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Perisphinctacean ammonites of the Late Jurassic in northern Switzerland

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Abstract

Systematic, bed-by-bed collecting from *in situ* in measured sections and from palaeontologic excavations in the formations of the Upper Oxfordian and of the Kimmeridgian in northern Switzerland yielded 1444, partly well-preserved perisphinctacean ammonites. 1146 of these were prepared, and most of the prepared specimens were measured. 144 of the measured perisphinctaceans were studied in detail. 57 formal taxa of specific rank are described and figured in this study. Five of these are new to science. 53 formal taxa of these perisphinctaceans are figured for the first time from northern Switzerland.

The studied ammonites evolved on average at a rate that time intervals of about 300 000 years can be discriminated. This is the mean temporal range of a morphospecies and of an ammonite subchron. For comparison, the age of these ammonites is on average 154 million years. The duration of about 300 000 years of an average ammonite subchron of the Late Jurassic is then 0.2% of the age of these subchrons (Gygi, 1999, fig. 1). Ammonites are the fossils with which the most accurate biostratigraphic correlations can be made in the Late Jurassic.

The fact that ammonites, like other marine biota, were sensitive to environmental conditions, was used to reconstruct the environment. The most important environmental control that was effective in ammonite communities was water depth. Water depth in meters was calibrated primarily with sedimento logic markers. A comprehensive study in sedimentary geolog was necessary to evaluate the bathymetric evidence of sedi mentologic markers down to the deep subtidal zone at abou 100 m. Ammonites were rare in very shallow water. Their per centage in the macrofauna increased with growing wate depth, and the composition of the ammonite fauna change with varying depth. Ammonite assemblages can therefore b used in order to interpolate water depths between sedimento logic depth markers in the deep subtidal zone, and to extrapo late depth in water deeper than 100 m.

Ammonites were less tolerant of a high rate of mud sedimen tation than certain hermatypic corals, but they could live per manently in water with an oxygen content that was 20% c even less of the normal level. They were strictly stenohalin because they are absent in sediments with evidence that the de posits were laid down in water with a salinity that was above c below normal. The pronounced sensitivity of ammonites t environmental conditions, mainly to water depth, is evidenc that most of these organisms lived in close relation to the bo tom of the sea. The perisphinctaceans described here are th ammonites best suited for biostratigraphic correlations withi the studied sediments, because they had the greatest toleranc of varying water depth.

Zusammenfassung

Systematisches Sammeln Schicht für Schicht aus dem Anstehenden in gemessenen Detailprofilen und in paläontologischen Grabungen in den Formationen des Oberen Oxfordian und des Kimmeridgian in der Nordschweiz ergab 1444, teilweise gut erhaltene Ammoniten aus der Superfamilie der Perisphinctaceen. Von diesen wurden 1146 Exemplare präpariert und die Mehrzahl davon gemessen. 144 der gemessenen Perisphinctaceen wurden im Detail untersucht. In der vorliegenden Arbeit werden 57 formelle Taxa im Rang von Spezies beschrieben und abgebildet, von denen fünf neu für die Wissenschaft sind. 53 der hier abgebildeten Perisphinctaceen-Taxa sind bisher noch nie aus der Nordschweiz abgebildet worden.

Die untersuchten Ammoniten veränderten sich mit der Zeit durchschnittlich mit einer solchen Geschwindigkeit, dass man anhand ihrer Entwicklung Zeiträume von etwa 300 000 Jahren unterscheiden kann. Dies ist die mittlere Dauer einer Morphospezies und eines Ammoniten-Subchrons. Das durchschnittliche Alter der untersuchten Ammoniten beträgt etwa 154 Millionen Jahre. Die durchschnittliche Dauer eines Ammoniten-Subchrons im Späten Jura von etwa 300 000 Jahren entspricht also 0,2% des Alters eines solchen Subchrons (Gygi, 1999, Fig. 1).

Die Tatsache, dass das Vorkommen von Ammoniten wie das von anderen marinen Organismen von Umweltbedingungen abhing, wurde für die Rekonstruktion der Lebensräume verwendet. Die Wassertiefe war für die Ammoniten der wichtigste Umweltfaktor. Die Bestimmung der Wassertiefen in Metern erfolgte primär mit sedimentologischen Mitteln. Voraussetzung dafür war eine gründliche Untersuchung der geolog schen Bildungsbedingungen der Sedimente, in welchen d gefundenen Ammoniten vorkommen. Die Sedimentologie e laubte, bathymetrische Marken bis auf eine Tiefe von etw 100 m zu erkennen. Ammoniten waren in sehr seichtem Wa ser selten. Ihr Anteil an der Makrofauna erhöhte sich m wachsender Wassertiefe, und die Zusammensetzung d Ammonitenfauna veränderte sich in Abhängigkeit von d Wassertiefe. Deshalb können Ammoniten-Vergesellschaftu gen dazu benützt werden, um in relativ tiefem Wasser zwische sedimentologisch bestimmten bathymetrischen Marken z interpolieren oder Wassertiefen von mehr als 100 m z extrapolieren.

Die Toleranz der Ammoniten gegenüber der Sedimentation geschwindigkeit von Schlamm war geringer als die von gewi sen hermatypischen Korallen. Dagegen konnten Ammonit dauernd in Wasser leben, dessen Sauerstoffgehalt 20% od weniger des normalen Wertes betrug. Die Ammoniten war stenohalin, weil sie in Sedimenten fehlen, welche in Wasser m einem nachweislich erhöhten Salzgehalt abgelagert wurd oder in Sedimenten mit Anzeichen eines verminderten Salzg halts des Wassers. Die ausgeprägte Empfindlichkeit der Ar moniten gegenüber Umweltbedingungen und besonders ih Abhängigkeit von der Wassertiefe zeigen, dass diese Tie mehrheitlich in enger Beziehung zum Meeresgrund gele haben. Die hier beschriebenen Perisphinctaceen sind diejer gen Ammoniten, welche sich für biostratigraphische Korrel tionen der untersuchten Sedimente am besten eignen, weil i Vorkommen am wenigsten von der Wassertiefe abhing.

1. Introduction

1.1 Fundamentals of stratigraphic geology: an overview

Northern Switzerland is relevant to stratigraphic and to sedimentary geology in general, because the term Jurassic is derived from a thick succession of marine, epicontinental sediments that crop out in the Jura Mountains. The greater part of this subordinate mountain range north of the Alps and north of the Swiss Plateau is in northern Switzerland. Sediments of Late Jurassic age in northern Switzerland are of special interest, because the notion facies was introduced into the geologic literature by Gressly (1838–1841). Gressly made his observations of facies in northern Switzerland in a platform to basin transition of sediments of Middle Oxfordian age. Oppel (1863:165), the founder of zonal stratigraphy, introduced the biostratigraphic "Zone des *Ammonites transversarius*". Oppel then stated that "the proper region of *Ammonites transversarius*" was the Birmenstorf Member in Canton Aargau, Switzerland. He included the "Impressa-Thone", now called Effingen Member, into this original Transversarium Zone *sensu lato*. In a subsequent paper that was published after his death by Waagen (Oppel & Waagen, 1866), Oppel specified that the Birmenstorf Member was the type of the revised Transversarium Zone. This is the oldest detailed account of an ammonite zone at all.

According to Geikie (1905, as quoted from the unabridged reprint of the book that was edited by Dover, New York, first in 1962 and then in an undated, second edition that is cited here, quoted from p. 338), the foundations of stratigraphic geology were laid in France by Abbé J. L. Giraud-Soulavé who lived from 1752 to 1813. This author declared on page 317 of chapitre VIII in his paper that was published in 1780, that the fossils he found in a succession of sediments on land, were the remains of organized beings that lived in an ancient sea. According to Geikie (1905, reprint, p. 344), A. L. Lavoisier (1743–1794), the father of modern chemistry, distinguished on page 350, plate 7 in a paper published in 1789, "littoral banks" from "pelagic banks" that were formed in the sea at different distances from land. The banks were marked by distinct kinds of sediment and by corresponding fossils. The succession of marine strata as was observed by Lavoisier also revealed that sea level oscillated in the past. Lavoisier (1789) thereby anticipated lateral facies changes and eustatism. To judge of Geikie (1905, reprint, p. 116), J.E. Guettard (1715–1786), who was engaged in geologic mapping of the whole of France, must have been aware of Lavoisier's insights, because Lavoisier assisted Guettard for some time in mapping. The result of this work was an atlas that was published by Guettard & Monnet (1780). All of the publications mentioned in this paragraph were referenced by Geikie and were not seen by the author.

A.G. Werner (1749–1817), a very influential teacher who lectured on mineralogy and on what he called geognosy at the mining school of Freiberg in northern Germany, discerned formations in vertical succession in the vicinity of Freiberg. According to Geikie (1905, reprint, p. 201–215), Werner thought that the formations were deposited by chemical precipitation in a primordial ocean, and that the formations could be correlated worldwide. Werner knew about fossils and interpreted them to have been formed by chemical precipitation just like the embedding rocks.

W. Smith (1769–1839) pioneered modern stratigraphy and the concept of palaeontology in England. He mapped the whole of England geologically. His map was published in 1815. The trailblazing "Strata identified by organized fossils" followed in 1816. An extended version of this, the "Stratigraphical system of organized fossils", was printed in 1817 and is referenced in the present study.

A. Gressly (1814–1865) followed, when he was a student of medicine between 1834 and 1836 at the University of Strasbourg, France, lectures on earth science given by P. L. Voltz. According to Meyer (1966:22), Gressly may have heard the term facies in Voltz's lectures. But it was Gressly (1838–1841:19–22) who introduced the notion facies into the geologic literature. He did this after preparing a geologic map of Canton Solothurn, northern Switzerland. Facies of a given sediment is characterized by both the lithology and by the fossils in the rock. Gressly stated that facies did not occur randomly in a sedimentary succession. He deduced and formulated rules of how facies succeed laterally and vertically in a sediment stack. Gressly's rules were visualized in a figure by Walther (1893/94:993) and became known as "Walther's law" in subsequent anglo-saxon literature on stratigraphy (see Krumbein & Sloss, 1963:318). Gressly (1838–1841, pl. 6) drew a palaeogeographic map of northern Switzerland. This may be the oldest of the kind that was ever published.

A.D. d'Orbigny (1802–1857) coined the stratigraphic term étage (stage). A. Oppel (1831–1865) subdivided these stages into zones. The Oppel zone is defined in a type area as a succession of strata that includes a distinct *assemblage* of fossils. The zone is named after a single fossil that is characteristic by its morphology, but can be rare as for instance the ammonite *Gregoryceras transversarium* (Quenstedt), the index of the Transversarium Zone. The holotype of the index of this zone is from Birmenstorf, Canton Aargau, Switzerland. Oppel defined the Transversarium Zone in Canton Aargau, where Gygi (1977:517), following Hedberg (1976:58), selected a reference section of the zone. The Transversarium Zone was redefined by Gygi (2000c). It can be used for intercontinental correlation in low palaeolatitudes, because the index of the ammonite zone was found as far away as Chile, from where it was figured by Gygi & von Hillebrandt (1991). The Transversarium Zone has now the rank of an international standard zone. This zone is documented by more than 3000 ammonites that were found *in situ* in the type area of the zone in northern Switzerland. A great number of these ammonites were figured in recent papers (see below).

A lucid lithostratigraphy in the modern sense was initiated in northern Switzerland by Moesch (1863), by Würtenberger & Würtenberger (1866), and mainly by Moesch (1867). These authors discerned and described "Schichten" (strata) that are lithologic units. Their "Schichten" have the rank of modern members. The authors gave geographic names to most of their members. Therefore, the names of the members can be used to the present day. Moesch as well as Würtenberger & Würtenberger were also ahead of their time in keeping lithostratigraphy separate from biostratigraphy. They added a separate list

of fossils to each of their lithologic description of "Schichten" or members.
Modern stratigraphy was initiated by Schenk & Muller (1941), who proposed to distinguish in the future "lithogenetic units from time-stratigraphic units and from units of time". Teichert (1958) pointed out the need to discern time-stratigraphic or chronostratigraphic units from biostratigraphic units. Wheeler (1958) stated that even the best guide fossils are sensitive to facies, and that biostratigraphic units are therefore heterochronous much like lithostratigraphic units. The imperfection of biostratigraphic units cannot be significantly improved by defining a biostratigraphic unit as an assemblage of fossils in order to reduce the shortcomings brought about by single heterochronous, facies-dependent taxa (see also Dunbar & Rodgers, 1961:284). Hedberg (1958) rejected the opinion that biostratigraphy was the only method of chronostratigraphy, or that biostratigraphy was identical with chronostratigraphy, an assertion that was later made by Schindewolf (1960:1).
Hedberg (1958) recommended to use any kind of marker horizons in combination with biostratigraphy in order to date even sediments that include no guide fossils or no fossils at all. Hedberg defined a chronostratigraphic unit to include all the sediments that were deposited during a given time span. He revised and completed the stratigraphic scheme by Schenk & Muller (1941). The outcome was the "Code of Stratigraphic Nomenclature" edited by the American Commission of Stratigraphic Nomenclature in 1961. This code was, with minor revisions, recommended for practical use by the "International Subcommission on Stratigraphic Terminology" (1961). Further revised and extended versions of the code are the stratigraphic guides edited by Hedberg (1976) and by Salvador (1994).

1.2 Previous work on stratigraphy in northern Switzerland

1.2.1 Litho- and biostratigraphy

Merian (1821) published the first geologic description of part of northern Switzerland. His stratigraphic account is lucid and essentially correct. Merian (1821) must have been aware of what William Smith had published about stratigraphy in England, because he stated on page 102 that lithologic comparisons alone were insufficient for time correlations, and that fossils were necessary for this purpose. But he stated on page 103 that the state of taxonomy of fossils at his time was as yet insufficient for time stratigraphy. So he correlated, with reservation, the limestone formation with hermatypic corals of the Gempen plateau south of Basel (now: St-Ursanne Formation) and of the Isteiner Klotz in southern Germany north of Basel with the younger, predominantly limestone succession with corals that is now called Günsberg Formation at the locality Wasserfalle south of Reigoldswil, Canton Basel-Landschaft. The older, pure carbonate St-Ursanne Formation is above what is now the argillaceous Bärschwil Formation, and the mainly carbonate Günsberg Formation is above the mostly argillaceous Wildegg Formation. This is represented in figure 173 of the present study. Merian (1821) thereby correlated the modern Bärschwil Formation with the modern Wildegg Formation that is now known to be younger.

Rengger (1829) gave a correct description of the Jurassic strata in the tabular Jura of Canton Aargau. The ammonite *Creniceras renggeri* (Oppel) is named after him, and the Renggeri Member (fig. 173) is called after Oppel's ammonite taxon that occurs in the lower part of the Renggeri Member. Gressly (1838–1841) mapped and described the geology of the Jura Mountains in Canton Solothurn. In 1864:94, he renamed the étage corallien Rauracien. According to Gressly (1838–1841, table on p. 166), the "Corallien" is above what was then called Terrain à Chailles (now: Sornetan Member). Gressly's Rauracien then encompasses the modern Liesberg Member and the St-Ursanne Formation above (fig. 173 of the present study).
The case of the "étage Corallien ou Rauracien" of Gressly (1864:94) illustrates the tendency of Swiss and French geologists to name and define stages after particular facies irrespective of time, as the stage name Corallien says. This led to a long-lasting confusion that began mainly when Marcou (1848:90) named a very incompletely exposed succession with siliceous sponges at the base "groupe argovien" near the village Andelot-en-Montagne, that is 9 km south-southeast of Salins in the Département Jura, France. Marcou named this particular succession in the area around Salins that he knew well "Argovien" after Canton Aargau in Switzerland (Argovie in French), where Marcou had seen what later became the Birmenstorf Member with siliceous sponges. Controversy later arose from the name Argovien, in the first place about whether the stratotype of the "Argovien" was at all in France as it was intended by Marcou, or whether it was in Switzerland. Secondly, nothing was known of the age of the "Argovien" at the time of Marcou. It was much later that it turned out that the "Argovien", as it was subsequently interpreted by mapping geologists in France, was of different facies and age than Marcou's type "Argovien" in France.
The following text was written in order to be an aid when reading geologic maps that are currently for sale and are used in the French and in the Swiss part of the Jura Mountains. The text hopefully gives an idea why it took the author 40 years to arrive at a reasonably well-understood picture of sedimentary geology during Late Jurassic time in the area, not to mention the invaluable help that was given to the author by numerous earth scientists who shared their knowledge with him.
In a railway cut north of Andelot in France, the succession in which Marcou (1848) defined his "groupe argovien" begins with the "Oxfordien", a blue-gray marl with small ammonite casts of iron sulfide. This is the equivalent of the Renggeri Member of modern Swiss geologists. The thickness of the "Oxfordien" near Andelot is not known. The type "Argovien" there begins with micritic limestone beds that include siliceous sponges and ammonites. The limestone beds alternate with intercalations of marl. This sediment stack that R. Enay showed to the author in 1965 is about 2.5 m thick. It closely resembles in facies and in thickness to what is now the Birmenstorf Member in Canton Aargau, Switzerland. Above the sponge limestone near Andelot are thick gray marls with intercalated beds of marly lime mudstone. This succession is very similar to the Effingen Member in northern Switzerland. The close resemblance in facies between the type Argovien near Andelot in France with what is now the Wildegg Formation (defined by Gygi, 1969:64) in Canton Aargau, Switzerland, is the reason why Marcou (1848:90) named his "groupe argovien" near Andelot after the Swiss Canton Aargau. The bedded lime mud-

stone of the Geissberg Member in the uppermost part of the Wildegg Formation as it was conceived by Gygi (1969) was later assigned by Gygi & Persoz (1986:407) to the pure carbonate Villigen Formation above.

Magné & Mascle (1964) revisited Marcou's "groupe argovien" near Andelot in France and justly called it stratotype of the "Argovien", this is to say the type section of the Argovian Stage that was used to that time in France, Switzerland and in Poland. Their figure 3 is a composite section of the incompletely exposed stratotype. The authors found the total thickness of the type "Argovien" near Andelot to be somewhat more than 100 m. The ammonite *Ochetoceras canaliculatum* (von Buch) is reported in their figure 3 to occur near the base of the "Argovien", in the facies that is similar to that of the Birmenstorf Member in Canton Aargau. *Perisphinctes (Dichotomosphinctes)* sp. gr. *wartae* Bukowski (whatever this means) was reported by Magné & Mascle (1964) to occur near Andelot in the upper part of the succession that resembles the Effingen Member in Switzerland. E. Glowniak from Warsaw recently identified specimens of *Perisphinctes wartae* Bukowski from the lower Effingen Member near Veltheim and Holderbank, Canton Aargau, in the collection of R. & S. Gygi at Basel. Glowniak (1997) has described and figured topotypes of the taxon from near Czestochowa, Poland. This is evidence that the lowermost part of the type Argovien near Andelot in France does not only resemble in facies to the Birmenstorf Member at the base of the Wildegg Formation in Canton Aargau, Switzerland, as was observed by Marcou (1848), but that the *type* Argovien in France is coeval with the Argovien of Swiss geologists except the Geissberg Member. Ziegler & Trümpy (1964:293) were of the opinion that the stratotype of the Argovien was in Switzerland, but they did not specify where they thought it was. Some French authors agree with them that the Argovien is not to be regarded as a French stage. The Argovian Stage is omitted in a compilation of French stages that was edited by Cavelier & Roger (1980).

The base of the "Argovien" north of Andelot is directly above the "Oxfordien" that is equivalent to the Renggeri Member of Swiss authors. The age of the Renggeri Member in normal thickness was documented near Liesberg, Canton Basel-Landschaft, by Gygi (1990b) with figured ammonites that were collected from *in situ*. The age of the member is there from the beginning of the Scarburgense Subchron to the end of the Costicardia Subchron. According to the ammonites as cited by Magné & Mascle (1964, fig. 3), the "Argovien" begins near Andelot above a hiatus. This corresponds with section RG 307 that was measured near Péry in Switzerland by Gygi (2000a, pl. 22). Section RG 307 in the quarry of La Charuque near Péry was perfectly exposed when measured by the author in 1980. The hiatus above the Renggeri Member in section RG 307 is documented with ammonites that occur directly below and above the hiatus. The ammonites from near Péry were found by A. and H. Zbinden and were figured by Gygi (1990b, pl. 5:4 and pl. 6:3).

According to Marcou (1848:95), there are "couches coralliennes" (strata with hermatypic corals) above his "Argovien" near Andelot. The same is the case in section RG 307 near Péry, where the correspondig unit above the Effingen Member is called Günsberg Formation. R. Enay found in 1965 the ammonite *Perisphinctes (Dichotomoceras) bifurcatus* (Quenstedt) in the lower part of the type section RG 14 of the Günsberg Formation near Günsberg, Canton Solothurn. The ammonite that R. Enay found there is number 18 in figure 173 of the present study. It was figured by Gygi (1995, fig. 17/2). The predominantly carbonate Günsberg Formation near Péry is of Bifurcatus age according to the mineral-stratigraphic correlations E and F by Gygi & Persoz (1986, pl. 1A). The coral limestone above the type "Argovien" near Andelot is probably coeval with the Günsberg Formation in Switzerland. This must be concluded from the ammonites that Magné & Mascle (1964, fig. 3) found in the "Argovien" below. Enay et al. (1988, fig. 6) assigned the coral limestone above the "Argovien" near Salins to the "Rauracien", this is to say to the older St-Ursanne Formation that is in fact coeval with the Birmenstorf Member in northern Switzerland (fig. 173 in the present study).

The Rauracien of Gressly (1864:94) is named after the Celtic tribe of the Rauracians that lived at the time of the Romans in northwestern Switzerland. There can be no doubt that northwestern Switzerland is the type area of the Rauracien, but Gressly did not designate a type locality. This predominantly calcareous unit with hermatypic corals is now called, with the exception of the Liesberg Member, St-Ursanne Formation (Bolliger & Burri, 1970:69). Pümpin (1965) found ammonites in the upper part of the formation in the limestone quarry near the railway station of St-Ursanne, Canton Jura. After 1970, Pümpin showed his ammonites from St-Ursanne to R. Gygi. R. Enay, during a visit to Basel, identified one of the ammonites to be *Perisphinctes (Perisphinctes) alatus* Enay that was later figured by Gygi (1995, fig. 4). Another specimen of Pümpin's ammonites was identified by R. Gygi to be *Perisphinctes (Dichotomosphinctes) dobrogensis* Simionescu that was figured by Gygi (1995, fig. 14). Representatives of the taxon *alatus* were excavated by R. and S. Gygi in 1970 and 1971 near Siblingen and Gächlingen in Canton Schaffhausen. The specimens were figured by Gygi (2001, fig. 85–87) from the Mumienkalk Bed in Canton Schaffhausen. *Perisphinctes (Dichotomosphinctes) dobrogensis* Simionescu as figured by Gygi (2001, fig. 168) was found in a block fallen from the lower Birmenstorf Member (normal, uncondensed facies) in the now closed iron mine near Herznach, Canton Aargau. These figured ammonites prove that the St-Ursanne Formation in northwestern Switzerland (the former Rauracien), the Birmenstorf Member in Canton Aargau and the Mumienkalk Bed in Canton Schaffhausen are coeval and are of Transversarium age. This is documented by the two encircled numbers 11 at the base of figure 173 that correspond to ammonites listed in figure 174 of the present study.

Gressly's Rauracien that includes the Liesberg Member below and the St-Ursanne Formation above (fig. 173), is above what Gressly (1838–1841, table on p. 166) called Terrain à Chailles. Merian (1821) and after him Gressly (1838–1841; 1864) correlated what is now the St-Ursanne Formation in northwestern Switzerland with the Villigen Formation in Canton Aargau. Accordingly, they correlated the modern Bärschwil Formation with the Wildegg Formation as was visualized by Gygi (2000a, fig. 3, upper left, compare with fig. 173 of the present study). After introduction of the Rauracien by Gressly (1864), French geologists followed Merian (1821) and assigned a Late Oxfordian age (in the modern sense) to their "Rauracien". As mentioned above, there is a coral limestone above the stratotype of Marcou's Argovien in France. Subsequent French authors thought that this coral limestone, a probable time equivalent of the Günsberg Formation in Switzerland that is very incompletely exposed near Andelot, was time-equivalent with Gressly's Rauracien. The Rauracien in the type region of northwestern Switzerland is above the Terrain à Chailles that is now called Sornetan Member, a marl with carbonate nodules that, according to Enay (1966:210), should correctly be called "sphérites" in French. Thurmann (1830:23) himself, the author of the name Terrain à Chailles, called the carbonate nodules in his member "sphérites". The Sornetan Member is older than Marcou's "Argovien" and, above all, it has a different facies. Nevertheless, subsequent French authors called the time equivalent of Thurmann's and Gressly's Terrain à Chailles below their "Rauracien" erroneously "Argovien".

The type Argovien of Marcou (1848) is now, on the strength of ammonites, known to be time-equivalent with the Swiss Wildegg Formation in the revised sense of Gygi & Persoz (1986). Consequently, the coral limestone above the stratotype of the Argovien near Andelot must be time-equivalent with the Swiss Günsberg Formation, not with Gressly's Rauracien. French geologists mapped for decades a vertical succession of "Oxfordien", a time equivalent of the Swiss Renggeri Member, and of an "Argovien" that is older than Marcou's type Argovien. The erroneous Argovien as was mapped by French geologists is now known to be coeval with the Swiss Sornetan Member. The "Rauracien" that the French mapped was thought to be a time equivalent of the Villigen Formation, and their "Séquanien" was believed to be of Kimmeridgian age. Gygi & Persoz (1986, pl. 1A) showed with the mineral-stratigraphic correlations E and F that were calibrated with ammonite biostratigraphy, that the lower part of the French "Séquanien" (now Röschenz Member in Switzerland, see fig. 173 of the present study) is of Bifurcatus age and thereby belongs to the Oxfordian.

While French geologists interpreted the Argovien and the Rauracien to be in vertical succession for the reasons given above, Rollier (1888) and mainly Rollier (1911, fig. 54) thought that Gressly's Rauracien passed laterally into the Argovien of Swiss authors that included the Geissberg Member at that time. Rollier's conclusion that Gressly's Rauracien and Marcou's Argovien were in fact coeval facies was accepted and followed for a long time by Swiss geologists. This view is illustrated in figure 1 by Ziegler & Trümpy (1964). The conflicting interpretations of the stages Oxfordien, Argovien, Rauracien and Séquanien by French and Swiss authors induced Arkell (1956:84) to abandon these four "stages" that were ill-defined at that time, and to replace them by an Oxfordian *sensu lato*. This solution was judged by Ziegler & Trümpy (1964:299) to be draconian and equivalent to cutting the gordian knot. Nevertheless, following Callomon (1964, table 2), Arkell's proposal was sanctioned by the majority of those who voted at the Colloque du Jurassique at Luxembourg in 1962. This congress recommended that the base of the Oxfordian Stage be placed at the base of the Mariae Zone, and the top of the stage at the top of the Pseudocordata Zone (Volume des Comptes rendus 1964:85).

Progress as compared with Rollier (1888 and 1911) was stimulated when Bolliger & Burri (1967) published the hypothesis that what is now called Röschenz Member, a peritidal sediment in the Central Jura, could be correlated with the Effingen Member that was laid down in the deeper water of the adjacent, epicontinental Rhodano-Swabian basin. Their means of correlation was detrital quartz and feldspar that they believed to have been blown into the environment by the wind. Thereby, Bolliger & Burri (1967) used minerals for the first time as a means of time correlation in Switzerland.

Certain beds (marl and limestone) in the Röschenz Member and in the Günsberg Formation include a high percentage of detrital quartz (Gygi, 2000a, fig. 15). Rollier (1898:58) stated that a carbonate bed in what is now the Röschenz Member near Damvant, a Swiss village adjacent to the French border west of Porrentruy, had a quartz content that was sufficient to use the rock in order to make grindstones. Ziegler (1962, pl. 42) drew attention to the small grain size and to the good sorting of detrital quartz grains in the Röschenz Member. He concluded from this that the quartz grains could have been transported by the wind into the environment. Bolliger & Burri (1967) adopted this view, but they did not give credit to Ziegler (1962). They found thin beds with abundant detrital quartz in the Effingen Member and thought that the quartz in these beds was also of aeolian origin.

Bolliger & Burri did not take the possibility into account that detrital quartz could be secondarily concentrated by water currents in the thin beds that they had observed in the Effingen Member. This member is a sediment from deeper water. Some of the thin beds with detrital quartz are turbidites as were figured by Gygi (1969a, pl. 4:12). Storms stirring up sediment at the seafloor can concentrate detrital quartz in tempestites that are conspicuous for instance in the uppermost Effingen Member of section RG 307 near Péry. Moreover, Bolliger & Burri (1967) paid no attention to the environmental significance of thin coal seams that were already mentioned to occur in the Röschenz Member by Heer (1885:125) and by subsequent authors. Oertli & Ziegler (1958, pl. 1) have figured characean gyrogonites and limnic ostracods from the Röschenz Member. This and the absence of evaporites in this member and in the Günsberg Formation is evidence that the climate was rather humid during deposition of these units. Aeolian transport of the detrital quartz sedimented at the scale observed in the units is therefore unlikely. Later it turned out that the morphology of the surface of the quartz grains as figured by Bolliger & Burri (1970) was not diagnostic of aeolian transport.

As a consequence of their postulated time equivalence of the Röschenz Member with the Effingen Member, Bolliger & Burri (1970, fig. 37) concluded that the St-Ursanne Formation passed laterally through the Pichoux Formation into the Birmenstorf Member. They visualized in figure 37 a platform to basin transition. But they disregarded the well-preserved, perisphinctid ammonites that their collegue V. Pümpin had previously found near St-Ursanne in the upper part of what Bolliger & Burri (1970:69) called St-Ursanne Formation. These ammonites could have been identified at that time using the comprehensive monograph by Enay (1966).

The deficiency of the arguments advanced by Bolliger & Burri (1967; 1970) in order to justify their correlations between facies from shallow and from deeper water made it plain that a better method of time correlation had to be found. R. and S. Gygi began in 1970 a systematic search for ammonites in the sediments from deeper water. This was done mainly in systematic, bed-by-bed excavations. The purpose was to supplement the very incomplete inventory of ammonites of Late Jurassic age in northern Switzerland. A complete ammonite biostratigraphy from the base of the Upper Jurassic to the Divisum Zone in northern Switzerland was addressed. However, this could only be achieved after working for more than 30 years in the present study (fig. 173–174). A substantial part of the ammonite specimens that came to light during this campaign, mainly among the perisphinctaceans of the Transversarium Chron, could not be identified using existing literature on taxonomy. A second step was to evaluate the entire stratigraphic work that was published on sediments of Late Jurassic age in northern Switzerland since Merian (1821). In addition, all the good sections in the central Jura Mountains were measured or remeasured, respectively, by the author in detail beginning in 1980. These sections were assembled in transects running perpendicularly to depositional strike following Ziegler (1962). F. Persoz sampled in 1980 the most complete sections that were measured by the author since 1962 for a complete mineral analysis.

Gygi & Persoz (1986) checked the correlations by Bolliger & Burri (1970) using a combination of mineral, bio- and of a refined lithostratigraphy. The clay mineral kaolinite proved to be especially useful for time correlations between sediments from land and from marine deposits. Gygi & Persoz (1986) found the correlations by Bolliger & Burri (1970) to be essentially valid. The work by Gygi & Persoz refined stratigraphy of the Late Jurassic in northern Switzerland. This was corroborated using ammonites as figured by Gygi (1995) and sequence stratigraphy (Gygi et al., 1998). Gygi (2000a) provided for a lithostratigraphic frame of reference in the sediments of Late Jurassic age in northern Switzerland that is based on 221 sections that were measured in detail. He compiled all the stratigraphic knowledge about these sediments and compiled a small dictionary of lithostratigraphic terms relating to them (Gygi, 2000b). Biostratigraphy presented in Gygi (2000a) was documented by short descriptions and figures of stratigraphically relevant ammonites of the Oxfordian and Kimmeridgian. The figured ammonites were selected out of an estimated 9000–10 000 ammonites that were collected mostly from *in situ* or that were systematically excavated in the area. More than 6000 of these ammonites are prepared and have an individual number.

1.2.2 Ammonites

1.2.2.1 Taxonomy

The earliest modern taxonomic work on ammonites from the investigated sediments is that by Oppel (1862/63). Many ammonites of Late Jurassic age as figued by Oppel from northern Switzerland were given to him by C. Moesch who figured but a few ammonites in his volume published in 1867. Then followed the monographs by de Loriol. Geyer (1961) figured some perisphinctaceans of Kimmeridgian age from northern Switzerland. Gygi (1977) revised the genus *Gregoryceras*. *Paraspidoceras* from the area were figured by Gygi et al. (1979). A study of Cardioceratinae from northern Switzerland was made by Gygi & Marchand (1982). This paper was supplemented by Gygi & Marchand (1993). Ammonites of Early and Middle Oxfordian age relevant to biostratigraphy from Liesberg and Péry were figured by Gygi (1990b). The vertical ranges of *Glochiceras, Creniceras* and *Bukowskites* were investigated and documented with figured specimens by Gygi (1991). Some *Amoeboceras* from northern Switzerland were figured by Atrops et al. (1993). *Tornquistes helveticus* (Jeannet) was revised using new material collected from *in situ* by Gygi et al. (1994). Ammonites found mainly in sediments from shallow water in northwestern Switzerland were figured by Gygi (1995).

Ammonites from the iron oolite directly below the Birmenstorf Member near Veltheim, Holderbank, Gansingen and Oberehrendingen in Canton Aargau as figured by Mangold & Gygi (1997) proved that the iron oolite is of Bathonian, not of Early Oxfordian age as was concluded by Gygi (1969a, pl. 2:4). The perisphinctaceans from the Early Oxfordian near Herznach were figured by Gygi (1998). Bonnot & Gygi (1998) figured Euaspidoceratinae of the Cordatum Subchron from near Herznach. Ammonites relevant to biostratigraphy from the latest Middle Jurassic to the Kimmeridgian were figured by Gygi (2000a). Marchand et al. (2000) figured ammonites of latest Callovian and Early Oxfordian age from Canton Aargau. The type Transversarium Zone in northern Switzerland was documented with a rich fauna of perisphinctaceans by Gygi (2001). Euaspidoceratinae from the Transversarium Zone in the same area were figured by Bonnot & Gygi (2001). The Grossouvrei Subzone could be documented for the first time in northern Switzerland with an ammonite fauna from Oberehrendingen, Canton Aargau. These ammonites that are kept in the collection of L. Rollier in the Geological Institute of the ETH Zürich were studied by R. Enay in Enay & Gygi (2001).

1.2.2.2 Ecology

Ziegler (1967) wrote a pioneering paper about ammonite ecology. He showed that ammonites are rare in very shallow water, and that the composition of the ammonite fauna varied between shallow and deeper water. Gygi in Gygi et al. (1979) discussed the ecology of the rare ammonite genus *Paraspidoceras*. Ammonite ecology was again investigated by Gygi (1999). The palaeobathymetric data presented before by Ziegler (1967) about the abundance of ammonites in relation to varying water depth could be confirmed in Gygi's paper. Additional evidence supporting Ziegler's conclusion that most ammonites lived at or in close relation to the seafloor could be given. Gygi (1999:132) concluded that ammonites could tolerate a permanently low oxygenation of the water they lived in. 1 milliliter of dissolved oxygen per liter of water or even less was estimated for the bottom water in which the Renggeri Member was laid down. A new result presented in that paper was that ammonites were less tolerant to a high rate of mud sedimentation than certain hermatypic corals.

1.2.3 Sedimentology

Pümpin (1965) investigated the sedimentology of the St-Ursanne Formation near St-Ursanne, Canton Jura. He showed in his figure 64 that the top of lagoon reefs in the upper St-Ursanne Formation could grow to about 20 m above the reef base. Pümpin read from the slight declivity of detritus aprons issuing from the reefs that the top of the reefs was never more than a few meters above the surrounding lagoon floor. Gygi (1969b) studied similar, Recent reefs in the lagoon of the Bermuda atoll. Gygi (1975) quantified bioerosion of reefs by parrot fish in Bermuda. Gygi (1969a) studied calcareous and iron oolites. Green (chamositic) and brown (goethitic) iron-ooids were found to occur embedded in lime mud in thin, widespread beds. Ammonites of normal size are abundant in the mud (Gygi, 1999, fig. 2). This and the mud-grade matrix of the thin beds of iron oolite is evidence that the beds are sediments from relatively deep and well-aerated water.

Gygi (1969a) identified small turbidites in the Effingen Member. Micritic lime mudstones were studied in ultrathin sections (thickness down to 1 micron, see pl. 12:43) with the petrographic microscope and with a transmission electron microscope. Bolliger & Burri (1970) figured for the first time stromatolites from the intertidal zone in sediments of Late Jurassic age in northern Switzerland. Gygi (1981) concluded that iron-ooids can be *accreted* in the marine environment when being rolled by episodic, oscillating currents during storms down to a maximum depth of about 100 m. Gygi & Persoz (1986; 1987) documented submarine debris flows in the Effingen Member and thereby gave additional evidence of the existence of depositional slopes. The bathymetry of stromatolites from the intertidal zone down to the floor of the epicontinental basin was investigated by Gygi (1992).

1.2.4 Sedimentary geology

The elements that are indispensable when trying to reconstruct sedimentary geology during the Late Jurassic in northern Switzerland were published in previous papers. Facies analysis of marine sediments was done by Gygi (1969a; 2000a). An autochthonous sediment formed on land is the palaeosol with rootlets in the Röschenz Member of section RG 398 near Liesberg, Canton Basel-Landschaft, that was figured by Gygi (2000a, fig. 25). The intertidal environment of the adjacent epicontinental basin was documented by Bolliger & Burri (1970) and by Gygi (1992) with stromatolites. Calcareous oolites as figured by Gygi (1969a) are evidence of very shallow marine water. A water depth of about 100 m was concluded by Gygi (1981) for the vertical and the lateral change from iron oolitic facies to mud-grade sediments including cauliflower, mature glauconite pellets that were formed at a depth greater than 100 m. Such a glauconite pellet in thin section from a limestone bed was figured by Gygi (1969a, pl. 4:15). Cauliflower glauconite pellets separated from a marl clay were depicted by Fischer & Gygi (1989, fig. 7).

Time correlation using a combination of mineral stratigraphy based mainly on the clay mineral kaolinite that was calibrated with biostratigraphy of ammonites collected from *in situ* (figured in papers cited above) was published by Gygi & Persoz (1986, pl. 1A). This was corroborated by the sequence stratigraphy presented by Gygi et al. (1998). Initial and final accommodation space of a particular, epicontinental succession can be read from Gygi (1986, fig. 3A–B). A shallowing-upward succession was recognized by Gygi (1969a:107) in the Effingen Member of Canton Aargau. Deepening-upward successions are recorded by the drowning of carbonate platforms like that of the Spatkalk Member near Veltheim (Gygi, 1986:458) or of the Dalle nacrée Member for instance in section RG 307 near Péry (Gygi, 2000a, pl. 22).

Relative sea-level changes are documented by rapid eustatic rises like that in the upper St-Ursanne Formation near St-Ursanne that drowned an active shoal of calcareous ooid sand and subsequently created a lagoon with coral patch reefs (Gygi, 1986, fig. 5). A gradual relative sea-level rise occurred during deposition of the Villigen Formation in Canton Aargau (Gygi, 1986:488). A relative sea-level fall led to exposure and subaerial erosion of the top of the sand shoal of calcareous ooids of the Balsthal Formation near Balsthal (Gygi, 2000a, fig. 37). Sedimentation rates varied greatly both vertically and laterally. Sedimentation ceased altogether in the whole region just before the beginning of the Late Jurassic. Then it greatly increased in northwestern Switzerland when succession 1 was laid down. This succession has an average, compacted thickness of 185 m in northwestern Switzerland, of 5–6 m in Canton Aargau and of but 0.5 m in Canton Schaffhausen (Gygi, 1986, fig. 3B, thicknesses represented in this figure are decompacted). Regional unconformities resulted when there was no sedimentation over an extended time span. Gygi (1986:467) emphasized that the hiatuses at the base of the Oxfordian near Liesberg or below the Pichoux Formation near Péry evolved by prolonged nondeposition in deep water.

It is evident from the geometry and from the internal structure of the investigated sedimentary bodies and from the palaeobathymetry (compare pl. 1A by Gygi & Persoz, 1986 with fig. 3 by Gygi, 1986) that the basement subsided during sedimentation. There was great regional variation in the amount of basement subsidence depending mainly on the shifting of sedimentary depocenters. Gygi (1986:488) concluded from this that loading of the lithosphere with sediments, an *exogenic* process, is quantitatively important. Loading with sediments leads to compaction of older sediments and to *isostatic* subsidence of the lithosphere below. Basement subsidence as caused by sedimentation varied at a given time so much over relatively short distances that flexural deformation of the lithosphere was ruled out by Gygi (1986:488). The differential, isostatic adjustment of the lithosphere as was caused by the great regional variation of sedimentation rates that is illustrated by succession 1 in figure 3B by Gygi (1986) must therefore have occurred along deep faults. This is a *tectonic* process that was driven by regional variation in sedimentation rates, this is to say by an *exogenic* cause.

The notion "tectonic subsidence" was previously used only for basement subsidence caused by processes in the earth interior (endogenic) as for instance cooling. It is evident from what has been said above that "tectonic subsidence" is an ambiguous term. This is why Gygi (1986) replaced it by the terms *endogenic subsidence* and *exogenic subsidence*. Differential movement along preexisting faults in the lithosphere during sedimentation can be driven by both endogenic and exogenic processes. Endogenic faulting during sedimentation of the St-Ursanne Formation is likely to be the cause of the great difference in thickness of the formation as mentioned by Gygi (1986:487) between about 95 m near Liesberg, Canton Basel-Landschaft (section RG 306, pl. 31 in Gygi, 2000a) and 35 m in the unpublished section RG 397 near Kleinlützel, Canton Solothurn, only about 4 km to the north-northwest (Gygi, 1990c, fig. 5). A divergent opinion relating to the cause of synsedimentary, regional variation in basement subsidence was since published in papers by Allenbach (2001; 2002) and by Wetzel et al. (2003) that are discussed below.

1.3 Provenance of the ammonites presented in this study

The bulk of the ammonites that are described and figured here was found in the lower Villigen Formation and in the lower Baden Member of section RG 70 at Mellikon, Canton Aargau (Gygi, 1969a, pl. 17). The location of section RG 70 and the locations of all the other sections mentioned here is indicated on the map of figure 1 in Gygi (2000a). The coordinates of these measured sections are listed in table 1 of the same study. Further ammonites were collected from the following sections:

RG 41 Brunegg, Canton Aargau, trench west of the castle: unpublished
RG 48 Baden, Canton Aargau, Martinsberg: unpublished
RG 57 Zeihen, Canton Aargau, quarry near Laufacher south of the former railway station of Effingen: unpublished
RG 61 Rüfenach, Canton Aargau, quarry southeast of the church Vorder Rein: unpublished
RG 65 Würenlingen, Canton Aargau, former quarry of cement works: unpublished
RG 66 Unterendingen, Canton Aargau, Tal: unpublished
RG 79 Neunkirch, Canton Schaffhausen, quarry at Tenggibuck: Gygi (1991, fig. 4)
RG 82b Siblingen, Canton Schaffhausen, alte Randenstrasse: Gygi (1991, fig. 3)
RG 82c Siblingen, Canton Schaffhausen, quarry at Steimürlichopf: Gygi (1969a, pl. 16)
RG 91 Immendingen, southern Germany, ooze of the Danube river: unpublished
RG 92 Möhringen, Baden-Württemberg, southern Germany: unpublished
RG 279 Siblingen, Canton Schaffhausen, same locality as RG 82b: Gygi (1991, fig. 3)

The sections labelled "unpublished" above are schematically represented in Gygi (1969a, pl. 19).
The ammonites that were collected since 1962 were taken by hand from *in situ* if possible. It must be taken into account that some of the described ammonites are very large, and some are giant. This means that collecting and preparation of such specimens required a lot of time. For instance, the holotype of *Ringsteadia magna* n.sp. was found in a quarry that is still worked. This ammonite has a diameter of 0.54 m. The coiling plane of the ammonite in the rock was horizontal, and the cast protruded only slightly from a vertical quarry face of tough, thickly-bedded limestone. Fortunately, compressed air was available at the site, and the quarry master gave the author a workman with a jackhammer for help. The workman and the author took turns operating the jackhammer. Even so, they spent a day and a half until the ammonite cast with much adhering rock could be heaved out of the artificial cavern. Preparation of the specimen in the laboratory took several days.
Large and complete ammonites are rare. Therefore, only a limited number of such specimens could be provided. Many ammonites from the glauconitic, marly limestone of the lower Baden Member of Mellikon were excavated with a bulldozer. In this case, the characteristic facies of the matrix of the recovered specimens made it possible to assign them exactly to bed no. 124 of section RG 70 (depicted in Gygi, 1969a, pl. 17) from which they were ripped by the bulldozer. This bed is only 1.1 m thick, but it represents most of the Platynota Zone and the whole of the Hypselocyclum Zone (fig. 170). The position in the biostratigraphic scale of most ammonites from bed no. 124 of section RG 70 could therefore be indicated only approximately in figure 170, even though the ammonites are from *in situ*. Some ammonite specimens were collected from the rubble of blasted rock. In this case, only the total vertical range of the numbered beds in the blasted succession could be recorded.

1.4 Methods of ammonite taxonomy used in this study

The ammonites published in this study were selected in three stages. All of the ill-preserved specimens were discarded at the excavation site. A second choice was made in the laboratory after washing the well-preserved specimens. Then it was decided what was going to be prepared. The final selection of what specimens were going to be used for detailed study was made after preparation. The consequence of this is that relatively few ammonites of the collected total are described and figured here.
The taxonomic procedure followed in this study was explained by Gygi (1977; 1998) and again by Gygi (2001). The conception of the "species" adopted is based strictly on morphologic features and is therefore artificial. The taxa of specific rank that are described here are therefore not meant to be biospecies. The descriptions are standardized in order to facilitate comparisons.
Cross-sections of ammonite whorls or of whole ammonites were drawn with a template former according to figure 7d in Gygi (2001). Cross-sections of very large specimens were drawn after a template made of soft, unelastic soldering wire.

1.5 Purpose of this study

It is the purpose of this study not only to publish perisphinctacean ammonites that are mostly new to northern Switzerland, but to give also a detailed review of the environment and of the history of sedimentation during the Late Jurassic of a classic succession of sedimentary rocks in northern Switzerland. Palaeoecology that was published in earlier papers by the author is here summarized and supplemented.
Few perisphinctaceans of Late Oxfordian and Kimmeridgian age from northern Switzerland were published to date. A considerable number of new material came to light during the last decades. The recently collected perisphinctaceans as well as some interesting forms from older collections are described and figured in this study. The taxonomic units of specific rank are conceived in a way that they can be used in high-resolution biostratigraphy.
It is emphasized that this study is regional. However, it is of interest beyond northern Switzerland, because it encompasses the strata and the macrofossils on which the former stage Rauracien (Gressly, 1864) was based. It is now known on the strength of ammonites that the entire Rauracien is of Transversarium age. The reference section of the Transversarium Zone is in Canton Aargau (Gygi, 1969a).
The ammonites that were collected by the author since 1962 and with the help of his wife Sylvia since 1970, mostly by hand

from *in situ*, were originally intended to serve as the foundation to a detailed biostratigraphy that was needed to reconstruct the depositional history of Late Jurassic sediments in northern Switzerland. Therefore, ammonite taxonomy was studied at an early stage only as a means for time correlation. But it soon turned out that very much collecting was needed to document all ammonite zones and subzones in the investigated area. For instance, a surface of more than 100 m^2 had to be worked in excavation RG 208 near Ueken, Canton Aargau, in order to find the very few ammonites that document the Densiplicatum and the Antecedens Subzones of the Oxfordian Transversarium Zone in the type area of the zone. Good representatives of the indices of the two subzones could only be found when several large excavations were made in Canton Schaffhausen, where the coeval strata are much more fossiliferous than in Canton Aargau. Much collecting was necessary in order to find representatives of the Divisum Subzone of the Kimmeridgian Divisum Zone. This is why ultimately more than 9000 ammonites were collected, a much greater number than was originally intended.
In spite of the thousands of collected ammonites, the Costicardia Subzone could only be documented by an ammonite given by the private collector B. Hostettler. The Grossouvrei Subzone was identified by R. Enay when he studied ammonites in the collection of L. Rollier that is kept in the ETH Zürich. The ammonites are from Oberehrendingen in Canton Aargau (Enay & Gygi, 2001). The Hypselum Subzone is documented by a single ammonite. This is the subzonal index J 27259 that D. Krüger found and gave to the author. It was figured by Gygi (2000a, pl. 10:1). The help of many specialists was needed in order to identify the important ammonite taxa correctly: F. Atrops (Lyon), A. Bonnot (Dijon), R. Enay (Lyon), C. Mangold (Lyon), D. Marchand and J. Thierry (Dijon) from France, G. Dietl and G. Schweigert (Stuttgart) and A. Zeiss (Erlangen) from Germany as well as E. Glowniak and A. Wierzbowski (Warsaw) from Poland. The perisphinctaceans published by Gygi (1998; 2000a; 2001) and in this study are not intended to be a revision of this superfamily. Such a revision would be far beyond of what the author could do. The purpose of the author's papers on the taxonomy of Swiss ammonites was mainly to give an inventory of what was found. This is why only some remarks will be made here on the phylogeny of Perisphinctaceae.
Gressly (1838–1841) was the first earth scientist in Switzerland who drew attention to the close relation between the lithology of marine rocks and the composition of their macrofauna on one hand and water depth on the other hand. Ziegler (1967) emphasized the importance of this and augmented the knowledge of the relation between the composition of the marine macrofauna and water depth. It is attempted here to give further evidence of this and especially of ammonite ecology. Details of ammonite ecology can only be understood when the depositional history in all of northern Switzerland during the Late Jurassic to Early Kimmeridgian time is reviewed. Both lithology and the whole macrofauna are considered in order to recognize the relation between the original water depth of the epicontinental basin, shallowing-upward and deepening-upward successions, sedimentation rates, relative sea-level changes and subsidence. A. Coe from England, F. Persoz (Neuchâtel) in Switzerland and P. R. Vail (Houston, Texas) from the USA gave the author great help in adopting new methods of time correlation.
A synthesis is here addressed between biostratigraphy based on ammonites combined with other methods of time correlation, sedimentology, rates of sedimentation, facies analysis and bathymetry in order to reconstruct the history of sedimentation. Then an attempt is made to calibrate macrofaunal associations with water depth in the late Transversarium Chron. These bathymetric data are used to estimate water depths in the lateral facies transition of the lower Reuchenette Formation to the lower Baden Member and to the lower Schwarzbach Formation. The initial depth of the studied epicontinental basin, shallowing-upward as well as deepening-upward successions with average sedimentation rates are adopted in a tentative reconstruction of synsedimentary tectonics.

1.6 How to use the reference collections

The reference collections relating to all publications by the author and colleagues since 1966 are kept in the Museum of Natural History at Basel. All of the measured stratigraphic sections and all the other localities have an individual number preceded by the suffix RG. These sections and localities are listed in a catalogue of RG-numbers that is kept with the main reference collection. Descriptions of the about 350 sections and localities are handwritten by the author in his field books numbered 1–13. The field books are stored with the main reference collection and can be consulted on request. A key is needed in order to evaluate the field books, because there are supplements to several sections that were measured at a later time. The supplements are therefore scattered further down in a given book or in following books. The key to use field books is an alphabetic catalogue of names of municipalities or townships like in a telephone directory. All of these names can be found on the Road Map of Switzerland 1:200 000 edited by the Bundesamt für Landestopographie, Wabern, Switzerland. Under a given township name in the author's catalogue are listed all entries in field books with number of book and page. An individual number preceded by the suffix Gy is handwritten on all objects in the reference collection relating to Gygi (1969a). In the reference collections relating to later publications by the author, only rock samples, thin sections and polished slabs carry a Gy-number. In these later collections, well-preserved cephalopods carry an individual number preceded by the suffix J. Cephalopods that were figured in previous publications or in this study, each with an individual J-number, are stored in separate reference collections.

1.7 Abbreviations

This study relies mainly on ammonites that were collected by the author and his wife Sylvia. All published specimens are kept in the Museum of Natural History, Basel (MNHB), at the present time. Some of the figured ammonites are in Basel as an unlimited loan from the Eidgenössische Technische Hochschule Zürich (ETHZ). Further abbreviations are explained in the text.

The following abbreviations are used in the tables of dimensions:

Dm	Diameter of the shell (in millimeters)
Wh	Whorl height
Wt	Whorl thickness
Um	Width of umbilicus
Ph	Diameter of the phragmocone
Nu	Nucleus (in specimens that are wholly septate)
Ur	Umbilical ribs
n	Number of umbilical ribs per whorl

Further abbreviations are:

aff.	Latin *affinis*, related to
cf.	Latin *conferre*, to compare
ETHZ	Eidgenössische Technische Hochschule, Zürich
FSL	Faculté des Sciences, Université Claude Bernard, Villeurbanne near Lyon, France
J	Prefix of the individual number of cephalopods kept in the Museum of Natural History, Basel
[M]	Macroconch ammonite
[m]	Microconch ammonite
MNHB	Museum of Natural History, Basel

An arrow beside an ammonite photograph indicates the position of the last septal suture line on a specimen with at least part of the body chamber. No arrow means that the specimen is either a wholly septate nucleus or that there is at least part of the body chamber, but the septal suture lines cannot be seen. No arrow is indicated if the body chamber of a specimen is longer than the entire last whorl.

2. Stratigraphy

The sections of the basinal facies, from which most of the ammonites published here were collected, were measured by Gygi (1969a). A first clarification of the depositional history in the shallow-water facies was given by Gygi & Persoz (1986) by a combination of refined lithostratigraphy, ammonite biostratigraphy and clay mineral stratigraphy. Gygi & Persoz (1986) also indicated that the Küssaburg Member in the Klettgau valley and in the Randen hills belongs to the upper Bimammatum Zone (Hauffianum Subzone). Gygi (1995) supplemented the ammonite biostratigraphy in the shallow-water facies. Sequence stratigraphy of the Late Jurassic of northern Switzerland was interpreted by Gygi et al. (1998). Gygi (2000a) presented a synopsis of his stratigraphic research since 1962. Detailed sections from the Central Jura are represented on numerous plates in the appendix of that book. The stratigraphic context of the lithostratigraphic units is represented in figure 173 of the present study. The age, zonation and correlation of the lithostratigraphic units mentioned in the taxonomic part of the present study can be read from figure 170 where the vertical ranges of ammonite taxa are indicated.

3. Taxonomy of perisphinctaceans of Late Oxfordian and Kimmeridgian age

3.1 Perisphinctaceans of the Villigen Formation (Oxfordian/Kimmeridgian)

3.1.1 Perisphinctaceans of the Crenularis and Hornbuck Members (Bimammatum Chron, Hypselum and Bimammatum Subchrons, Late Oxfordian)

Class Cephalopoda Cuvier, 1797

Order Ammonoidea Zittel, 1884

Superfamily Perisphinctaceae Steinmann, 1890

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Lithacosphinctes* Olóriz, 1978

Type species: Ammonites lictor evolutus Quenstedt, 1887 [M].

Remark: It is concluded of recent research on perisphinctaceans of the Transversarium Zone (Gygi, 2001) and of the fact that *Lithacosphinctes* occurs already in the Effingen Member of Canton Aargau, that *Lithacosphinctes* evolved from *Liosphinctes* of the Luciaeformis Subzone of the Transversarium Zone. *Lithacosphinctes* is best assigned to the subfamily Perisphinctinae. Classification of *Lithacosphinctes* as a genus (not as a subgenus) agrees with Hantzpergue (1989:118), but disagrees with Atrops (1982), who interpreted *Lithacosphinctes* to be a subgenus of *Orthosphinctes* Schindewolf, 1925.

Lithacosphinctes latecosta (Dohm, 1925) [M]
Fig. 1–3; table 1

v * 1925 *Pictonia latecosta* n.sp. – Dohm, p. 32, pl. 9:6.
1963 *Decipia (Pomerania) latecosta* (Dohm) – Enay, p. 40, pl. 2:1, 2.
1966 *Decipia latecosta* (Dohm) – Enay, p. 557, fig. 171:2–4, fig. 173, fig. 174:4–9, pl. 39:2.

Holotype: University of Greifswald, northern Germany, Institute of Geology, without number, plate 9:6 in Dohm (1925).

Type locality: Quarry near Czarnoglowy (= former German Zarnglaff), Poland.

Type horizon: Upper Jurassic.

Description: The carbonate internal mould of MNHB J 32763 is septate to the diameter of 270 mm. The body chamber occupies three quarters of the last whorl and is complete with the peristome. The peristome has an extended S-curvature. The section of the body chamber is thick-oval. The inner whorls are flattened. The primary ribs of the inner whorls begin at the umbilical suture line. They are straight and radial, low and blunt until the diameter of about 250 mm. The primary ribs are very faint at the diameter of 180 mm. No secondary ribs are visible. They must fade out before the end of the phragmocone. From the diameter of 250 mm on, the distance of the primary ribs increases (fig. 1), and the ribs become stronger. On the first quarter whorl of the body chamber, the primary ribs are swollen and cuneiform. They fade out completely at the siphonal side. Then the primaries become simple, swollen ridges on the sides of the body chamber. These ridges fade almost entirely at the siphonal side. The height of the last three ribs gradually decreases towards the peristome. The peristome itself is compressed. The last whorl covers the preceding one by 25%.

Affinities: Only the last whorl of the holotype is preserved. The type is septate to the diameter of 270 mm, and the body chamber occupies three quarters of the last whorl. At the beginning of the body chamber, five primary ribs are cuneiform. The greatest diameter of the holotype is 410 mm. The last septa are not approximated, and the peristome is not preserved. However, the whorl thickness decreases towards the end of the body chamber. This is an indication that the type is nearly complete. The number of primary ribs per whorl is 19 at the diameter of 410 mm. This and the cuneiform ribs at the beginning of the body chamber of the holotype compare very well with MNHB J 32763 which is figured here. The whorl section of the type is thick-oval, and the siphonal side is smooth. On the other hand, the ornamentation of J 32763 is very similar to the material described by Enay (1966). But the size of J 32763 is somewhat inferior to both the holotype and to some of the French specimens. The diameter of the phragmocone varies between 270 and 296 mm in the Swiss material (table 1).

Material: 4 specimens: MNHB J 30512, J 30518, J 30519, J 32763.

Lithacosphinctes villae n.sp. [M]
Fig. 4–6; table 2

Holotype: MNHB J 30510, figure 4.

Type locality: Section RG 70, Mellikon, Canton Aargau.

Type horizon: Not from *in situ*, collected out of rubble blasted from a succession of beds no. 4–10 of section RG 70, Lower Villigen Formation.

Derivation of the name: The name is in honour of Mr. Alexander Villa, machine operator, Mellikon, who donated numerous, scientifically interesting ammonites to the Museum of Natural History, Basel.

Fig. 1. *Lithacosphinctes latecosta* (Dohm), MNHB J 32763.
Section RG 66, Tal east of Unterendingen, Canton Aargau, bed no. 16: Crenularis Member.
Coll. R. Gygi & B. Ziegler. ×0.5.

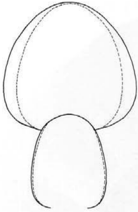


Fig. 2. Whorl section of *Lithacosphinctes latecosta* (Dohm), MNHB J 32763. ×0.5.

Individual labelling of specimen	Ph	Dimensions, mm				in % of Dm			Ur/whorl	
	mm	Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 30512	296	349	80	76	190	23	22	55	370	16
									300	33
									260	40
									220	45
									180	44
									140	44
									100	44
									60	48
MNHB J 30519	293	381	94	87	201	25	23	53	380	17
MNHB J 30518	275	371	85	87	209	23	23	56	370	19
									220	44
									180	49
									140	49
									100	49
									60	47
MNHB J 32763	270	386	96	85	220	25	22	57	386	21
									340	28
									300	39
									260	54
									220	58
									180	52
									140	54
									100	51
									60	51

Table 1. Dimensions of *Lithacosphinctes latecosta* (Dohm).

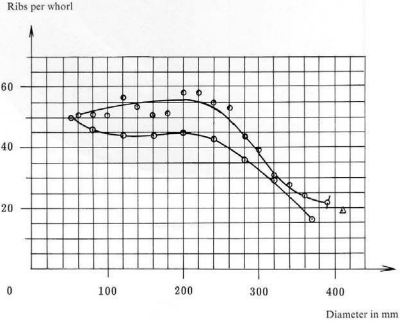


Fig. 3. Rib curves of *Lithacosphinctes latecosta* (Dohm).
Circles: upper curve: MNHB J 32763, lower curve: MNHB J 30512;
triangle: holotype.

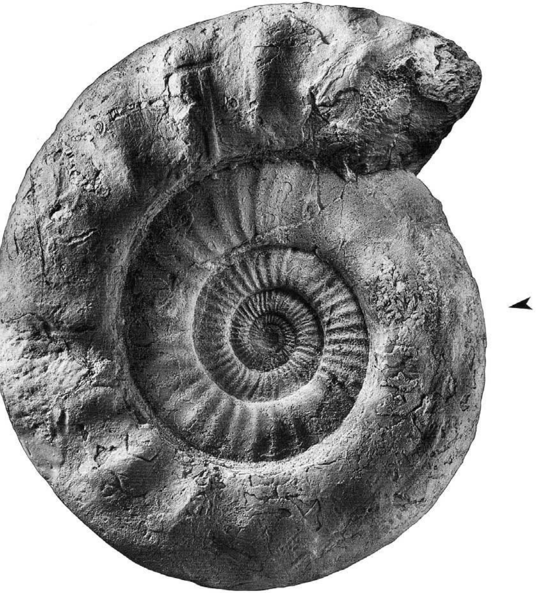


Fig. 4. *Lithacosphinctes villae* n.sp., MNHB J 30510, holotype.
Section RG 70, large quarry, Mellikon, Canton Aargau, not from *in situ*, collected from rubble blasted out of beds no. 4–10 of section RG 70: lower Villigen Formation.
Coll. A. Villa. ×0.6.

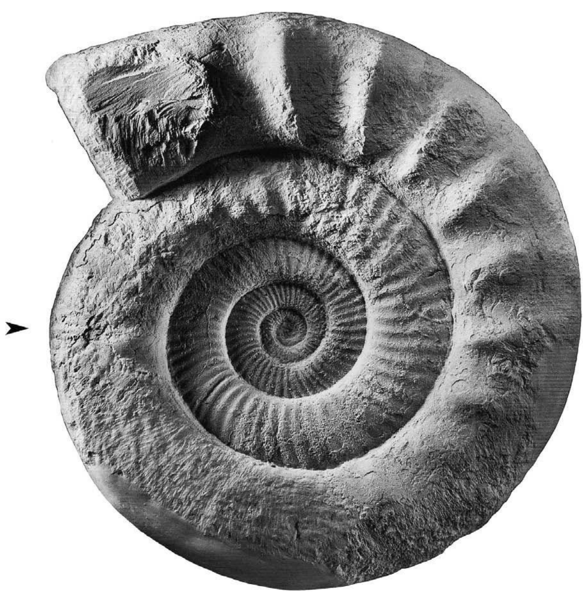


Fig. 5. *Lithacosphinctes villae* n.sp., MNHB J 24373, paratype.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 7: lower Villigen Formation.
Coll. A. Villa. ×0.6.

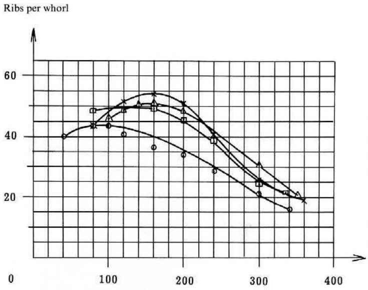


Fig. 6. Rib curves of *Lithacosphinctes villae* n.sp.
Circles: holotype, MNHB J 30510;
triangles: MNHB J 24373;
crosses: MNHB J 30515;
quadrangles: MNHB J 24379.

Diagnosis: Very large form (for classification of size see Gygi, 2001:12) of the genus *Lithacosphinctes*, the phragmocone of which has a diameter of between 228 and 240 mm and which grows to a final size of 320–360 mm. The section of the last whorl is thick-oval. The primary ribs of the inner whorls are distinct and sharp. On the body chamber they are simple, swollen ridges.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 30515	240	356	87	83	195	24	23	55	360	19
									300	26
									240	41
									200	51
									160	54
									120	52
									80	44
MNHB J 24373	235	335	83	-	186	25	-	56	350	21
									300	31
									240	39
									200	48
									160	52
									120	49
									100	46
MNHB J 24379	230	337	80	63	187	24	19	56	337	22
									300	24
									240	38
									200	~46
									160	~49
									80	48
MNHB J 30510 Holotype	228	318	86	78	164	27	25	51	340	16
									300	22
									240	28
									200	34
									160	37
									120	41
									100	43
									40	40

Table 2. Dimensions of *Lithacosphinctes villae* n.sp.

Description: The carbonate internal mould of the holotype MNHB J 30510 is septate to the diameter of 228 mm. Three quarters of the last whorl are occupied by the body chamber. The body chamber is nearly complete, because the last visible primary rib is attenuated and has an abnormally strong forward inclination. The peristome is not preserved. The section of the last whorls is thick-oval. The rounded umbilical wall of the last whorl is relatively steep. The primary ribs of the innermost whorls are distinct and sharp-edged. They begin at the umbilical suture line and swing back on the umbilical wall. Already at the diameter of 70 mm, the primary ribs become low and blunt. They have a forward inclination of 0–8°. They are subdued at the end of the phragmocone. The secondary ribs fade out before the end of the phragmocone. Traces of them are visible where the end of the last whorl of the holotype touches the preceding whorl at the diameter of 205 mm. The primary ribs at the beginning of the body chamber are simple, low ridges that progressively grow stronger until at the diameter of 300 mm. From there to the end of the body chamber their strength diminishes. The siphonal side is smooth. The last whorl covers the preceding one by 36%.

Affinities: Lithacosphinctes villae n.sp. resembles *Lithacosphinctes latecosta* (Dohm). The principal difference between the two taxa is that in size. *Lithacosphinctes villae* n.sp. has end-diameters of adult specimens that vary between 320 and 360 mm. The diameter of phragmocones of this taxon is from 228 to 240 mm. In Swiss representatives of *Litha-*

cosphinctes latecosta (Dohm), the end-diameter of adults is between 385 and ca. 410 mm, and the diameter of phragmocones 270–296 mm. It could be argued that the gap in size between the two taxa might be closed, if more material was available. But the rib curves of *Lithacosphinctes villae* and *Lithacosphinctes latecosta* studied here also differ systematically: The curve of *Lithacosphinctes villae* begins to descend at the latest at the diameter of 160 mm, whereas the curve of *Lithacosphinctes latecosta* from Switzerland descends only from diameters exceeding 200 mm. It must be noted that the rib curves of specimens attributed to *Lithacosphinctes latecosta* by Enay (1966, text-fig. 173) begin to descend earlier than in Swiss representatives of this taxon. Nevertheless, it seems to be advisable to retain the name *villae* at least for the time being for the Swiss material. *Lithacosphinctes villae* n.sp. is smaller than *Lithacosphinctes robustus* (Dohm). In Dohm's taxon, the middle part of the body chamber is thicker than high (depressed), what is mainly caused by the greater strength of the ribs as compared with *Lithacosphinctes villae* n.sp. *Pomerania helvetica* (Geyer) in Wierzbowski (1978, pl. 4:1) is also similar, but it is smaller and above all younger (Planula Zone).

Material: 4 specimens: MNHB J 24373, J 24379, J 30510, J 30515.

Differential diagnosis: Lithacosphinctes villae n.sp. differs from otherwise similar *Lithacosphinctes latecosta* (Dohm) in size. The diameters of the holotype of *Lithacosphinctes latecosta* and of further, adult representatives of that taxon from northern Switzerland vary between 385 and 410 mm (phragmocones: 270–296 mm). The diameters of adult *Lithacosphinctes villae* are between 320 and 360 mm (phragmocones: 228–240 mm). The rib curves of *Lithacosphinctes villae* begin to descend at the latest at a diameter of 160 mm as compared with at least 200 mm in *Lithacosphinctes latecosta* from northern Switzerland.

Lithacosphinctes serotinus n.sp. [M]

Fig. 7–10; table 3

1963 *Lithacoceras (Lithacoceras) pseudolictor* (Choffat) – Koerner, p. 365, text-fig. 60–61, pl. 23:2.

Holotype: MNHB J 32764, figure 7.

Type locality: Section RG 66, Tal east of Unterehrendingen, Canton Aargau.

Type horizon: Bed no. 15 of section 66, Crenularis Member.

Derivation of the name: serotinus, Latin for acting late, refers to the very late appearance of distant, swollen gerontic ribs during ontogeny.

Diagnosis: Very large form of the genus *Lithacosphinctes*, the phragmocone of which has a diameter of between 175 and 210 mm. The taxon grows to a diameter not greater than about 320 mm. The section of the last whorl is oval. The inclination of the umbilical wall is slight at the end of the body chamber of adults. Simple, swollen gerontic ribs appear only on the last third of the body chamber.

Description: The carbonate internal mould of the holotype J 32764 is septate to the diameter of 190 mm. The body chamber occupies seven eighths of the last whorl. The peristome is not preserved. The whorl section is oval. The siphonal side of the last half of the body chamber is compressed, presumably because of diagenetic deformation. On the phragmocone the primary ribs begin close to the umbilical suture line. On the body chamber the umbilical wall is smooth, and the primary ribs begin only at the umbilical margin. The primary ribs are proconcave. They split at only about 50% of the whorl height into four to five weak secondary ribs. The point of division is indistinct. The secondary ribs have the same forward inclination as the upper part of the primary ribs. They fade away at the diameter of about 220 mm. The rib curve (fig. 10) is much like part of a circle. The inclination of the umbilical wall becomes slight at the end of the body chamber. Simple, swollen umbilical ribs appear only at the last third of the body chamber.

Affinities: Lithacosphinctes serotinus n.sp. resembles *Lithacosphinctes villae* n.sp. to some extent, but there are the following differences: The final size of *Lithacosphinctes serotinus* is somewhat less than in *Lithacosphinctes villae* n.sp. The umbilicus of *Lithacosphinctes serotinus* is narrower. The secondary ribs continue to the body chamber. Simple swollen ridges appear only on the last third of the body chamber. These gerontic ribs appear later in ontogeny and are less vigorous than in *Lithacosphinctes villae* n.sp. The inclination of the umbilical wall towards the end of the body chamber of *Lithacosphinctes serotinus* is less than in *Lithacosphinctes villae* n.sp. The curvature of the rib curves of the two taxa is also different.

Lithacosphinctes pseudobreviceps (Simionescu, 1907:168, text-fig. 32, pl. 8:1) is also closely related with *Lithacosphinctes serotinus* n.sp. The holotype of Simionescu's taxon is probably a nearly complete adult, because the last two preserved ribs are subdued. If so, Simionescu's taxon is somewhat smaller. It has a wider umbilicus and thicker whorls. The inclination of the umbilical wall is greater than in *Lithacosphinctes serotinus* n.sp. The rib curve of *Lithacosphinctes pseudobreviceps* (Simionescu) culminates already at the diameter of 100 mm with 53 primary ribs. It then falls to 32 ribs at the diameter of 200 mm as compared with 46 ribs at the same growth stage in *Lithacosphinctes serotinus* n.sp. (fig. 10). As Enay (1966:527) remarked, *Lithacosphinctes pseudobreviceps* (Simionescu) is unrelated to *Perisphinctes pseudobreviceps* Wegele (1929b:54, pl. 3:2) that is of the Platynota Chron.

Material: 4 specimens: MNHB J 24375, J 30517, J 32764, J 32767.

Differential diagnosis: Lithacosphinctes serotinus n.sp. differs from *Lithacosphinctes villae* n.sp. in its somewhat smaller size and in the narrower umbilicus. The secondary ribs continue to the body chamber, whereas the gerontic ribs appear later in ontogeny and are less vigorous than in *Lithacosphinctes villae* n.sp. *Lithacosphinctes serotinus* n.sp. differs from *Lithacosphinctes pseudobreviceps* (Simionescu, 1907, non Wegele, 1929b) in its somewhat greater size and in the narrower umbilicus. The whorls are more compressed.

Fig. 7. *Lithacosphinctes serotinus* n.sp., MNHB J 32764, holotype.
Section RG 66, Tal east of Unterendingen, Canton Aargau, bed no. 15: Crenularis Member,
Coll. R. Gygi & B. Ziegler. ×0.7.

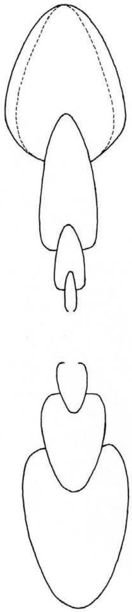


Fig. 8. Cross-section of *Lithacosphinctes serotinus* n.sp., MNHB J 32764, holotype. ×0.7.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 30517	210	296	80	60	147	27	20	50	320 260 200	32 41 43
MNHB J 32767	205	276	71	57	134	26	21	49	290 260 200 140 100 50	25 33 44 48 47 41
MNHB J 32764 Holotype	190	282	76	56	134	27	20	48	290 260 200 140 100	29 39 48 44 43
MNHB J 24375	175	247	78	-	108	32	-	44		

Table 3. Dimensions of *Lithacosphinctes serotinus* n.sp.

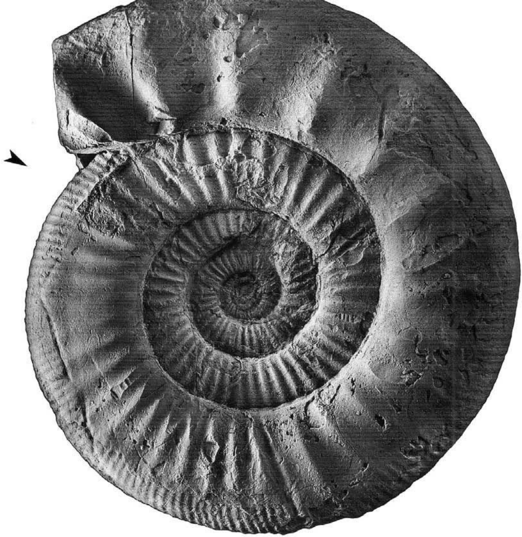


Fig. 9. *Lithacosphinctes serotinus* n.sp., MNHB J 30517, paratype.
Section RG 70, large quarry, Mellikon, Canton Aargau, not from *in situ*, collected out of rubble blasted from beds no. 4–10 of section RG 70: lower Villigen Formation. Coll. A. Villa. ×0.6.

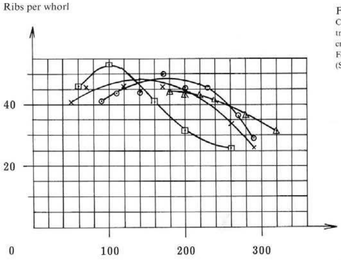


Fig. 10. Rib curves of *Lithacosphinctes serotinus* n.sp.
Circles: holotype, MNHB J 32764,
triangles: MNHB J 30517;
crosses: MNHB J 32767.
For comparison, quadrangles: *Lithacosphinctes pseudobreviceps* (Simionescu).

Genus *Orthosphinctes* Schindewolf, 1925

Remark: Atrops (1982) included *Orthosphinctes* in the subfamily Ataxioceratinae and regarded *Lithacosphinctes* to be a subgenus of *Orthosphinctes.* Atrops (1982) was certainly right to assume that *Orthosphinctes* and *Lithacosphinctes* are closely related. Because of this and of the remark above, *Orthosphinctes* is here included in the subfamily Perisphinctinae.

Subgenus *Pseudorthosphinctes* Enay, 1966 [M]

Type species: Orthosphinctes (Pseudorthosphinctes) alternans Enay, 1966 [M].

Orthosphinctes (Pseudorthosphinctes) alternans Enay, 1966 [M]
Fig. 11–13; table 4

1966 *Orthosphinctes (Pseudorthosphinctes) alternans* n.sp. – Enay, p. 520, fig. 158, fig. 159:1, with synonymy.

Holotype: Faculté des Sciences Lyon (FSL) 75.709, figure 159:1 in Enay (1966).

Type locality: Bouvesse, Département Isère, France.

Type horizon: Couches de Bouvesse, Bimammatum Subzone.

Description: The carbonate internal mould of MNHB J 24380 is of a complete adult with part of the peristome. The septal suture lines are not preserved. The whorl section is oval and compressed and is much higher than thick. The primary ribs originate at the umbilical suture line on the inner whorls and higher up on the umbilical wall on the last whorl. They are straight from the beginning and have a forward inclination of 0–9°. The low and blunt primary ribs split at 70% of the whorl height into two or three weak secondary ribs. The secondaries have a slightly stronger forward inclination than the primaries and form an indistinct proconvex arc on the siphonal side. They are not attenuated at the siphonal side. The last whorl covers the preceding one by 23%.

Affinities: The final size of specimen MNHB J 32768 is about 225 mm. J 32768 is septate to the diameter of 130 mm. The dimensions of this specimen compare well with those given by Enay (1966) in his table on page 523. However, the umbilicus is narrower in the Swiss material than in the holotype. The possibility must be taken into account that the described material is microconch because of the regular ornamentation and the steadily rising rib curve.

Material: 3 specimens: MNHB J 24380, J 32768, J 32769.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32768	130	190	57	36	87	30	19	46	225	63
MNHB J 24380	?	171	52	31	78	31	18	46	200 160 120 100 60	59 55 51 51 47
MNHB J 32769	122	137	40	36	64	29	26	46	140 100 60 30	55 53 49 45

Table 4. Dimensions of *Orthosphinctes (Pseudorthosphinctes) alternans* Enay.

Fig. 11. *Orthosphinctes (Pseudorthosphinctes) alternans* Enay, MNHB J 24380.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 3: lower Villigen Formation.
Coll. A. Villa. ×1.

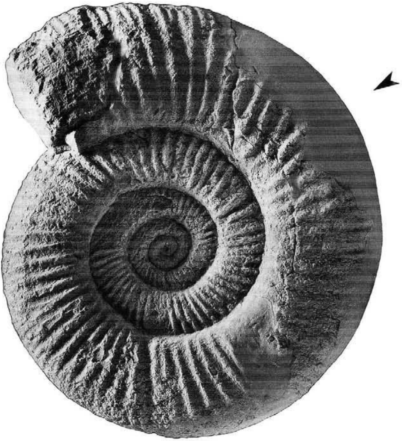


Fig. 12. *Orthosphinctes (Pseudorthosphinctes) alternans* Enay, MNHB J 32769.
Section RG 48, Martinsberg, Baden, Canton Aargau, bed no. 45: Crenularis Member.
Coll. R. Gygi. ×1.

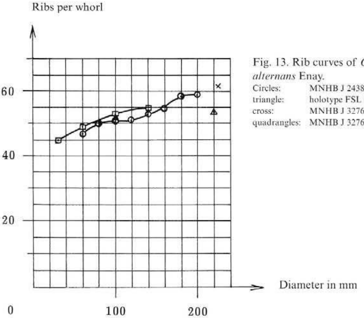


Fig. 13. Rib curves of *Orthosphinctes (Pseudorthosphinctes) alternans* Enay.
Circles: MNHB J 24380;
triangle: holotype FSL 75.709;
cross: MNHB J 32768;
quadrangles: MNHB J 32769.

Orthosphinctes (Pseudorthosphinctes) n.sp. Enay, 1966 [M]
Fig. 14–15; table 5

1966 *Orthosphinctes (Pseudorthosphinctes)* n.sp. – Enay, p. 524, fig. 158, fig. 160:1–2, with synonymy.

Description: The carbonate internal mould of MNHB J 24385 is septate to a diameter of at least 112 mm. About one fifth of the last whorl is occupied by the body chamber. The septal suture lines are indistinct. The whorl section is oval and compressed. The primary ribs begin on the inner whorls at the umbilical suture line and are radial. On the last whorl they begin on the rounded umbilical wall. They are straight on the inner whorls and become somewhat proconcave on the last whorl. They split into two to three secondary ribs at 62% of the whorl height. The secondary ribs are relatively strong and are not attenuated at the siphonal side. They are slightly inclined forward and form a proconvex arc at the siphonal side.

Affinities: The specimen J 24385 figured here is similar to FSL 75.654 as figured by Enay (1966, fig. 160:2) but its umbilicus is narrower. The state of preservation of J 24385 is insufficient for a holotype.

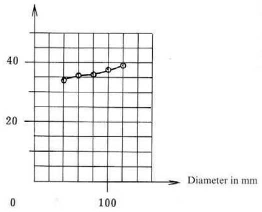


Fig. 15. Rib curve of *Orthosphinctes (Pseudorthosphinctes)* n.sp. Enay.

Fig. 14. *Orthosphinctes (Pseudorthosphinctes)* n.sp., Enay, MNHB J 24385.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 2: lower Villigen Formation.
Coll. A. Villa. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24385	112?	117	41	30	49	35	25	42	120	39
									100	38
									80	36
									60	36
									40	34

Table 5. Dimensions of *Orthosphinctes (Pseudorthosphinctes)* n.sp. Enay.

Subgenus *Orthosphinctes* Schindewolf, 1925 [m]

Type species: Ammonites tiziani Oppel, 1863 [m].

Orthosphinctes (Orthosphinctes) tiziani (Oppel), 1863 [m]
Fig. 16–17; table 6

Synonymy: see Enay (1966:514).

Lectotype: Page 44, plate 1:4 in Wegele (1929b).

Type locality: Hundsrücken near Streichen, Württemberg, southern Germany.

Type horizon: According to Oppel (1863:246): Hauffianum Subzone of the Bimammatum Zone.

Description: The carbonate internal mould of MNHB J 24381 is septate to the diameter of 58 mm. Three fourths of the last whorl are occupied by the body chamber. The whorl sides are subparallel and only slightly convex. The siphonal side is

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24381	58	81	23	-	41	28	-	50	89 60 40	44 40 37

Table 6. Dimensions of *Orthosphinctes (Orthosphinctes) tiziani* (Oppel).

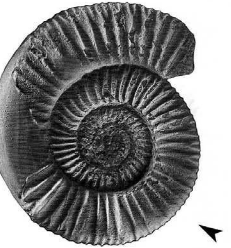


Fig. 16. *Orthosphinctes (Orthosphinctes) tiziani* (Oppel), MNHB J 24381.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 3: lower Villigen Formation.
Coll. A. Villa. ×1.

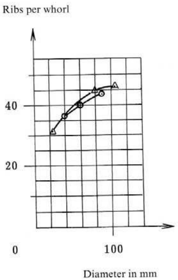


Fig. 17. Rib curves of *Orthosphinctes (Orthosphinctes) tiziani* (Oppel).
Circles: MNHB J 24381;
triangles: lectotype after the photograph in Wegele (1929, pl. 1, fig. 4a).

rounded as in the lectotype (Wegele, 1929b, pl. 1:4b). The umbilical wall is rounded. The primary ribs begin at the umbilical suture line. Most of them are straight from the beginning and are radial. Some of the primary ribs on the inner whorl lean forward as much as 10°. On the last whorl some of them lean backward. Three primary ribs of the body chamber are enhanced. The primaries split at 70% of the whorl height into two secondary ribs. Intercalated secondaries are rare. The secondary ribs have the same direction as the primaries on the body chamber. The last fifth of whorl of the body chamber is pressed off the coiling plane. Therefore, it cannot be established how much the last whorl covers the preceding one.

Affinities: The dimensions of J 24381 agree well with those of the lectotype. The last septum of the lectotype is, to judge of the photograph in Wegele (1929b, pl. 1:4a), at the diameter of 65 mm. The lectotype has a diameter of 110 mm. It is then larger than J 24381.

Material: 1 specimen: J 24381.

Orthosphinctes (Orthosphinctes) ponii (Simionescu, 1907) [m]
Fig. 18–19; table 7

1907 *Perisphinctes Ponii* n.f. – Simionescu, p. 130, text-fig. 7, pl. 1:2, pl. 6:2.

Lectotype: Plate 1:2 in Simionescu (1907), designated here.

Type locality: Cekirgea, Dobrogea, Romania.

Description: The carbonate internal mould of MNHB J 24382 is compressed in the axial plane that coincides with the line of the greatest diameter. The primary diameter of the mould before compression must have been about 150 mm. The dimensions (table 7) were measured in an axial plane inclined 45° to the plane of greatest compression. The specimen is septate to the diameter of about 93 mm. Seven eighths of the last whorl are occupied by the body chamber that is complete to a constriction and a bulge before the peristome. The peristome itself is not preserved, but on the figured side of the mould, part of a lappet is visible. This specimen is therefore a microconch. The whorl section cannot be measured, because the greater part of the body chamber is probably diagenetically compressed in the equatorial plane. The last whorl of the phragmocone is even flattened. The primary ribs begin on the rounded umbilical wall and there swing back. They are straight on the whorl sides and lean about 5° forward. The point of division into two to three secondary ribs is at a variable height above the umbilical suture line. The secondary ribs have the same direction as the primaries and are not attenuated at the siphonal side. The last whorl covers the preceding whorl only slightly.

Affinities: The lectotype which apparently is near-complete has a diameter of 160 mm as compared with about 150 mm of the complete J 24382 before deformation. The umbilicus of the three specimens measured by Simionescu is somewhat wider (Simionescu, 1907:130) than that of the specimen figured here. The density of the primary ribs is almost identical in J 24382 with that in the lectotype as far as primary ribs are visible on the lectotype. On the lectotype there are either fair

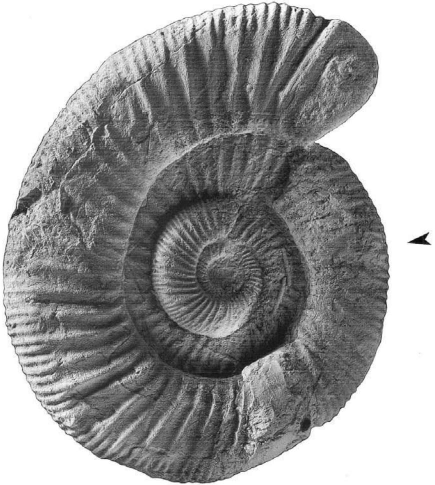
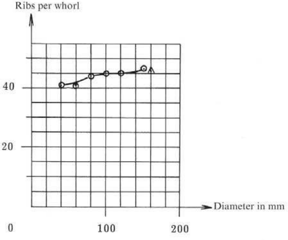


Fig. 18. *Orthosphinctes (Orthosphinctes) ponii* (Simionescu), MNHB J 24382.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 3: lower Villigen Formation.
Coll. A. Villa. ×1.



Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24382	~93	148	43	22	74	29	15	50	~150 ~120 ~100 ~80 ~60 ~40	47 45 45 44 42 41

Table 7. Approximate dimensions of *Orthosphinctes (Orthosphinctes) ponii* (Simionescu).

Fig. 19. Approximate rib curve of *Orthosphinctes (Orthosphinctes) ponii* (Simionescu).
Circles: MNHB J 24382;
triangle: lectotype.

or enhanced primary ribs on the last quarter whorl of the body chamber. Such an irregularity occurs in J 24382 at the beginning of the body chamber.

The dimensions of the *Ammonites triplicatus albus* figured by Quenstedt (1887 in 1887/88, pl. 100:8) are very close: Dm: 156 mm, Wh: 0.29, Wt: 0.23, Um: 0.49. But the phragmocone of Quenstedt's specimen has a diameter of 136 mm, and the greatest diameter of the complete shell must have been at least 200 mm. The German specimen has only 33 primary ribs at the diameter of 40 mm as compared with 41 primaries at the same diameter in J 24382. At the diameter of 150 mm, both specimens have 47 primary ribs.

Orthosphinctes (Pseudorthosphinctes) alternans Enay is also similar, but it is as well larger than *Orthosphinctes (Orthosphinctes) ponii* (Simionescu). The ribbing of Enay's taxon is somewhat denser than in the Romanian form.

Material: 1 specimen: MNHB J 24382.

Subgenus *Praeataxioceras* Atrops, 1982 [m]

Type species: Perisphinctes laufenensis Siemiradzki, 1899 [m].

Orthosphinctes (Praeataxioceras) laufenensis (Siemiradzki, 1899) [m]

Fig. 20–21; table 8

1899 *Perisphinctes Laufenensis* n.sp. – Siemiradzki, p. 188, text-fig. 33, pl. 26:46.

pars 1940 *Perisphinctes laufenensis* Siemiradzki – Dieterich, pl. 2:9.

pars 1963 *Perisphinctes (Orthosphinctes) laufenensis* Siemiradzki – Koerner, p. 359, text-fig. 56–57, pl. 25:2, pl. 30:1.

Holotype: Plate 26:46 in Siemiradzki (1899).

Type locality: Laufen, Württemberg, southern Germany.

Type horizon: According to Siemiradzki (1899 in 1898/99:188): Tiziani Zone.

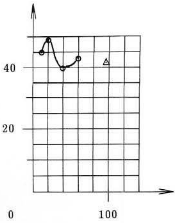


Fig. 21. Rib curve of *Orthosphinctes (Praeataxioceras) laufenensis* (Siemiradzki).
Circles: MNHB J 32770;
triangle: MNHB J 32771.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32771	~55	98	34	29	40	34	29	41	98	42
MNHB J 32770	50	57	21	17	22	37	30	39	60 40 20 10	43 40 49 45

Table 8. Dimensions of *Orthosphinctes (Praeataxioceras) laufenensis* (Siemiradzki).

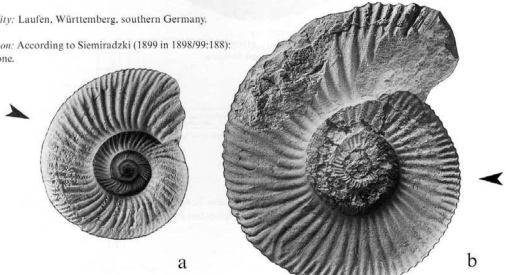


Fig. 20. *Orthosphinctes (Praeataxioceras) laufenensis* (Siemiradzki).
a: MNHB J 32770, section RG 92, Möhringen, southern Germany, Württemberg, bed no. 9: Hornbuck Member;
b: MNHB J 32771, section RG 82b, old Randen road, Siblingen, Canton Schaffhausen, bed no. 18: Hornbuck Member.
Coll. R. Gygi. ×1.

Description: The carbonate internal mould of MNHB J 32771 is septate to the diameter of ca. 55 mm. The septal suture lines are very incompletely visible. The body chamber occupies about three quarters of the last whorl. It ends with a deep constriction before the peristome. The peristome is not preserved. The whorl section is oval. The primary ribs begin on the rounded umbilical wall. They are straight from the beginning and lean 10° forward. They split at 67% of the whorl height into two secondary ribs. There are some intercalated secondary ribs. The secondary ribs have the same direction as the primaries. They are strong and blunt and are not attenuated at the siphonal side. There is a very pronounced parabolic node on the body chamber. The umbilical wall touches the preceding whorl at an angle of 90°. The smaller specimen MNHB J 32770 (fig. 20a) has proconcave primary ribs that have a forward inclination of more than 20°.

Affinities: The rib curve of J 32770 between the diameters of 20 and 60 mm resembles to that of *Dichotomoceras* of the Bifurcatus Zone. The inner whorls of that specimen have some similarity to *Ammonites virgulatus* Quenstedt (1887 in 1887/88, pl. 100, fig. 5). However, the original to Quenstedt's figure is much more densely ribbed. *Ammonites Streichensis* Oppel (1863, pl. 66:3) has a much narrower umbilicus and is more densely ribbed than J 32770.

Material: 2 specimens: MNHB J 32770, J 32771.

Orthosphinctes (Praeataxioceras) sp. A [m]

Fig. 22–23; table 9

1887 *Ammonites polygyratus* – Quenstedt, p. 923, pl. 100:6.

v 2000a *Orthosphinctes (Praeataxioceras)* sp.gr. *laufenensis* (Siemiradzki) – Gygi, p. 95, fig. 58, pl. 11:1.

Description: A specimen that belongs to this taxon was described and figured by Gygi (2000a:95, text-fig. 58, pl. 11:1). It is larger than MNHB J 27793 which is figured here. J 27793 is diagenetically deformed. Its rib curve (fig. 23) descends after the diameter of 40 mm as is normally the case in macroconchs. There are parabolic nodes at the transition phragmocone-body chamber.

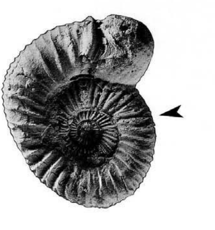


Fig. 22. *Orthosphinctes (Praeataxioceras)* sp. A, MNHB J 27793.
Section RG 279, old Randen road, Siblingen, Canton Schaffhausen, bed no. 8: Hornbuck Member.
Coll. R. & S. Gygi. ×1.

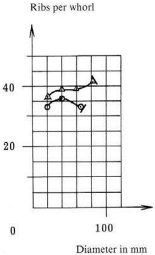


Fig. 23. Rib curves of *Orthosphinctes (Praeataxioceras)* sp. A.
Circles: MNHB J 27793;
triangles: MNHB J 31722.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 31722 Holotype	52	82	26	16	39	32	20	48	82 60 40 20	42 39 39 36
MNHB J 27793	~40	65	18	18	30	28	28	46	65 40 20	33 36 33

Table 9. Dimensions of *Orthosphinctes (Praeataxioceras)* sp. A.

Affinities: Orthosphinctes (Praeataxioceras) sp. A resembles *Nautilus polygyratus* Reinecke (1818:73, pl. 5:45–46). The holotype of *Nautilus polygyratus* could not be found in the Naturkunde-Museum at Coburg, Germany, where part of Reinecke's types are kept. Geyer (1961:21, pl. 1:4), who did not yet know that part of Reinecke's types are at Coburg, designated a neotype, *Perisphinctes (Orthosphinctes) polygyratus*, from the Schwarzbach Formation in the Randen hills, northern Switzerland. Schairer (1974:52) and Atrops (1982:51) accepted this even though Zeiss in Heller & Zeiss (1972:35) remarked that Geyer's neotype must be regarded at best as preliminary referring to article 75c (5) of the International Code of Zoological Nomenclature (1964). To conclude of Reinecke (1818:73) and Schairer (1974, fig. 60), it is very probable that the holotype of *Nautilus polygyratus* Reinecke is from the Platynota Zone at Mt. Staffelberg above the village of Staffelstein in the Franconian Alb, southern Germany.

Orthosphinctes (Praeataxioceras) sp. A is smaller than the neotype of *Perisphinctes (Orthosphinctes) polygyratus* (Reinecke) in Geyer (1961, pl. 1:4). It has a narrower umbilicus than Geyer's neotype, and above all it is much older. Gygi (2000a:95) thought that what is now *Orthosphinctes (Praeataxioceras)* sp. A was related to *Orthosphinctes (Praeataxioceras) laufenensis* (Siemiradzki). However, it is evident from the rib curves in figures 21 and 23 that the innermost whorls of *Orthosphinctes (Praeataxioceras) laufenensis* are considerably more densely ribbed than those of *Orthosphinctes (Praeataxioceras)* sp. A.

Material: 2 specimens: MNHB J 27793, J 31722.

Orthosphinctes (Praeataxioceras) sp. B [m]

Fig. 24; table 10

1887 *Ammonites polygyratus* – Quenstedt, p. 921, pl. 100:1.

Description: The carbonate internal mould of MNHB J 24376 is of a complete adult with the entire body chamber and a deep constriction before the peristome. The peristome is broken off. No septa are visible. The whorl section is ellipsoidal and compressed where it is apparently undeformed. The primary ribs begin at the umbilical suture line and are straight from the beginning. They lean 4–9° forward. They are low, but sharp. The primary ribs split at 65% of the whorl height into two to three secondary ribs. The secondaries have the same direction as the primaries. There are parabolical nodes. The last whorl covers the preceding one so little that the points of division of the primary ribs are visible on the last but one whorl.

Fig. 24. *Orthosphinctes (Praeataxioceras)* sp. B, MNHB J 24376.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 5: lower Villigen Formation.
Coll. R. & S. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24376	?	53	17	-	25.5	32	-	48	53 30	41 41

Table 10. Dimensions of *Orthosphinctes (Praeataxioceras)* sp. B.

Affinities: The specimen MNHB J 24376 resembles *Orthosphinctes (Praeataxioceras)* sp. A in the ribbing with parabolical nodes. The density of the ribbing at comparable diameters is also very similar. But the umbilicus of J 24376 is much wider than that of *Orthosphinctes (Praeataxioceras)* sp. A at the diameter of 50 mm. The size of J 24376 is smaller than that of *Orthosphinctes (Praeataxioceras)* sp. A J 27793 (fig. 22). The two forms are probably not conspecific.

Material: 1 specimen: MNHB J 24376.

Family Aulacostephanidae Spath, 1924

Subfamily Pictoniinae Spath, 1924

Genus *Ringsteadia* Salfeld, 1913

Type species: Ammonites pseudocordatus Blake & Hudleston, 1877 [M].

Remarks: Three taxa of generic rank have been included by Arkell in Arkell et al. (1957:324) in his genus *Ringsteadia: Ringsteadia* Salfeld, 1913, *Vineta* Dohm, 1925, and *Balticeras* Dohm, 1925. Arkell et al. (1957) interpreted *Vineta* to be a younger synonym of *Ringsteadia. Vineta* Dohm is certainly a macroconch. The only *Ringsteadia pseudocordata* figured by Salfeld (1917, pl. 10:1) is wholly septate. This is probably a macroconch. If so, Arkell in Arkell et al. (1957) was right in rating *Ringsteadia* and *Vineta* as synonyms. The question arises what are microconchs of *Ringsteadia.* Specimen J 32762 which is figured here (fig. 30) might be a microconch, but no septal sutures are visible. Moreover, the specimen is deformed. No indubitable microconch *Ringsteadia* was as yet figured. Consequently, the genus *Ringsteadia* is not subdivided into subgeneric taxa here. *Balticeras* Dohm was found to be younger (Hypselocyclum Chron) than true *Ringsteadia. Balticeras* seems to be related rather to *Involuticeras* Salfeld, 1913 than to *Ringsteadia.*

Ringsteadia limosa (Quenstedt, 1888)

Fig. 25–26; table 11

v 1888 *Ammonites limosus* – Quenstedt, p. 1068, pl. 124:3.
1970 *Ringsteadia (Ringsteadia) limosa* (Quenstedt) – Wierzbowski, p. 275, pl. 3.
1978 *Ringsteadia (Ringsteadia) limosa* (Quenstedt) – Wierzbowski, pl. 3:4.

Holotype: University of Tübingen, Museum für Geologie und Paläontologie, without number, plate 124:3 in Quenstedt (1888).

Type locality: Laufen an der Eyach, southern Germany.

Type horizon: Weisser Jura β (after Quenstedt, (1887/88).

Description: The carbonate internal mould of MNHB J 32759 is septate to the diameter of 285 mm. About two thirds of the last whorl are occupied by the body chamber. The peristome is not preserved. The whorl section at the end of the last whorl,

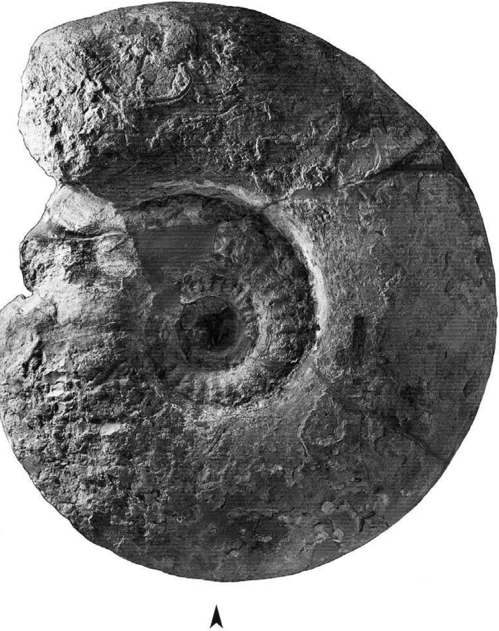


Fig. 25. *Ringsteadia limosa* (Quenstedt), MNHB J 32759.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 9: lower Villigen Formation, found by C. Wyss.
Coll. R. Gygi. ×0.5.

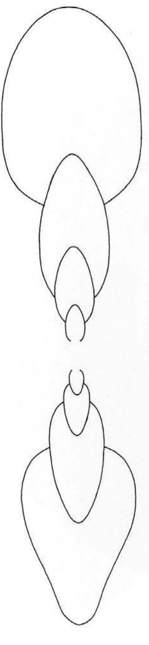


Fig. 26. Cross-section of *Ringsteadia limosa* (Quenstedt), MNHB J 32759. ×0.5.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32759	285	405	128	-	158	32	-	39	250 220	29 28

Table 11. Dimensions of *Ringsteadia limosa* (Quenstedt).

at the diameter of 405 mm, is ellipsoidal (fig. 26), but it is high-oval at the diameter of about 220 mm on the phragmocone. The inclination of the umbilical wall is slight on all of the preserved ontogenetic stages. There are 29 primary ribs at the diameter of 250 mm. There is a distinct egression of 1.4 (as calculated after Gygi, 2001:14) of the umbilical suture line on the last half whorl at the diameter of 403 mm. This and the change in the whorl section on the body chamber are indications that the specimen is adult.

Affinities: The holotype of *Ringsteadia limosa* (Quenstedt) has a diameter of 141 mm. Septa are visible to a diameter of at least 100 mm, but the holotype could well be a wholly septate nucleus. The umbilicus of the holotype is only 33% of the diameter as compared with 39% of the probably adult MNHB J 32759. The holotype has 31 primary ribs per whorl at the diameter of 60 mm and 30 primaries at the diameters of 100 and 141 mm. The specimen figured by Wierzbowski (1970, pl. 3) may be a juvenile.

Material: 1 specimen: MNHB J 32759.

Ringsteadia cf. *submediterranea* Wierzbowski, 1978

Fig. 27–29; table 12

1978 *Ringsteadia (Ringsteadia) submediterranea* n.sp. – Wierzbowski, p. 322, pl. 3:1–3, with synonymy.

Holotype: University of Warsaw, Institute of Geology W 85 Mi/2, plate 3:1 in Wierzbowski (1978).

Type locality: Bobrowniki, Poland.

Type horizon: Miedzno chalky limestones.

Description: The glauconitic, carbonate internal mould of MNHB J 32760 is septate to the diameter of 205 mm. Only a quarter whorl of the body chamber is preserved. The whorl section is high-oval at the end of the phragmocone. The umbilical wall of the inner whorls is steep and the umbilicus deep. The inclination of the umbilical wall progressively diminishes on the last whorl and is very slight at the end of the preserved part of the body chamber. There are 31 primary ribs at the diameter of 150 mm. The primary ribs are weak, straight and radial. The primary and the indistinct secondary ribs fade away at the end of the phragmocone. There is a conspicuous egression of 1.6 of the umbilical suture line on the last half whorl at the diameter of 233 mm. Therefore, the specimen is probably adult.

Affinities: The holotype of Wierzbowski (1978, pl. 3:1) is smaller and more involute than J 32760 as described here. There are more primary ribs per whorl in the Polish material as compared with the Swiss specimens. The umbilicus of the inner whorls of *Ringsteadia limosa* (Quenstedt) is much shallower, and this taxon is larger. *Ringsteadia pseudoyo* Salfeld is similar, but the ornamentation in this taxon fades away earlier than in *Ringsteadia submediterranea* Wierzbowski.

Material: 2 specimens: MNHB J 32760, J 32761.

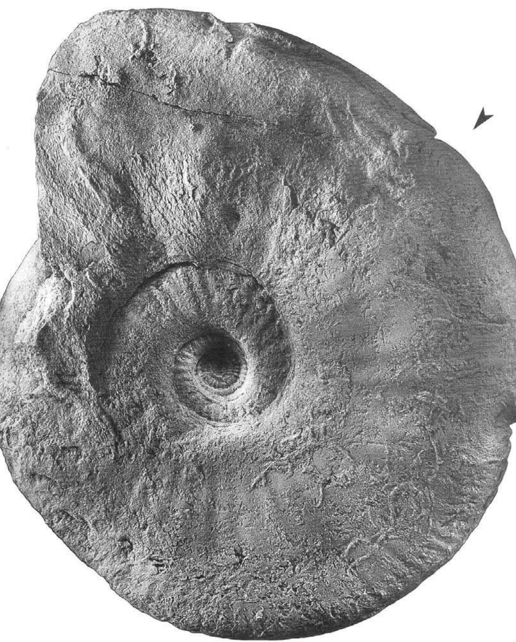


Fig. 27. *Ringsteadia* cf. *submediterranea* Wierzbowski, MNHB J 32760.
Section RG 48, Martinsberg, Baden, Canton Aargau, bed no. 45: Crenularis Member.
Coll. M. Tièche, unlimited loan of ETH Zürich. ×0.9.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32760	205	212	84	48	53	40	23	25	150	31
MNHB J 32761	Nu	108	56	28	15	52	26	14		

Table 12. Dimensions of *Ringsteadia* cf. *submediterranea* Wierzbowski.

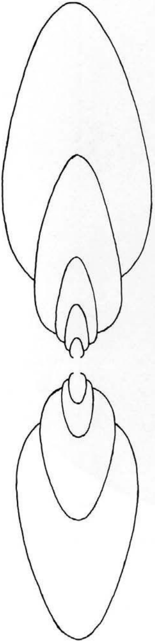


Fig. 28. Cross-section of *Ringsteadia* cf. *submediterranea* Wierzbowski, MNHB J 32760. ×1.

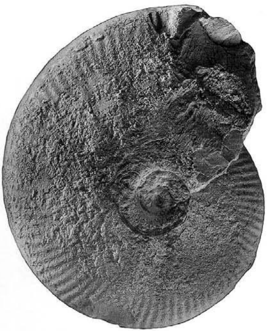


Fig. 29. *Ringsteadia* cf. *submediterranea* Wierzbowski, MNHB J 32761.
Section RG 61, quarry southeast of the church Vorder Rein, Rüfenach, Canton Aargau, bed no. 19: Crenularis Member.
Ex coll. L. Rollier, unlimited loan of ETH Zürich. ×1.

Ringsteadia flexuoides (Quenstedt, 1887)
Fig. 30

1970 *Ringsteadia (Ringsteadia) flexuoides* (Quenstedt) – Wierzbowski, p. 273, pl. 1:1–3, pl. 2:1–2, with synonymy.

Holotype: University of Tübingen, Museum für Geologie und Paläontologie, plate 107:15 in Quenstedt (1888).

Type locality: Laufen, Württemberg, southern Germany.

Type horizon: Weisser Jura β. Bimammatum faunal horizon after Schweigert & Callomon (1997).

Description: The carbonate internal mould of MNHB J 32762 is deformed and cannot be measured. No septal sutures are visible. The deformed whorl section is ellipsoidal. There are 27 radial primary ribs on the last whorl. These split at about 50% of the whorl height into three secondary ribs. Some of the secondary ribs have the same direction as the primaries, but some of them bend forward. Both the primary and the secondary ribs are quite strong.

Affinities: Quenstedt's holotype is somewhat more densely ribbed than MNHB J 32762, but the whorl section of the two specimens is similar. There are no secondary ribs bending forward in the holotype.

Material: 1 specimen: MNHB J 32762.

Fig. 30. *Ringsteadia flexuoides* (Quenstedt), MNHB J 32762.
Section RG 82b, old Randen road, Siblingen, Canton Schaffhausen, bed no. 23: Hornbuck Member.
Coll. R. Gygi. ×1.

Ringsteadia magna n.sp. [M]
Fig. 31–34; table 13

Holotype: MNHB J 32644, figure 27.

Type locality: Section RG 70, large quarry, Mellikon, Canton Aargau.

Type horizon: Bed no. 6 of section RG 70, lower Villigen Formation.

Derivation of the name: The taxon is the largest known to date among *Ringsteadia.*

Diagnosis: Giant species of the genus *Ringsteadia.* The phragmocone of adults has a diameter between 310 and 370 mm. The maximum diameter of complete adults is as much as 540 mm. The section of the inner whorls is high-oval with the greatest thickness at about one third of the whorl height. The umbilical wall of the innermost whorls is vertical. The inclination of the umbilical wall diminishes markedly from the umbilical width of 25 mm and is slight later in ontogeny. The whorl section of some individuals can be oxycone at diameters between 250 and 400 mm. The whorl section at the end of the last whorl of complete adults is ellipsoidal. The ornamentation fades away at the latest at an umbilical width of less than 50 mm. There is a conspicuous egression of the umbilical suture line on the last whorl.

Description: The carbonate internal mould of the holotype MNHB J 32644 is septate to the diameter of 370 mm. Two thirds of the last whorl are occupied by the body chamber. The greater part of the peristome is preserved on the left side of the holotype (fig. 31). The inner whorls of the taxon (in specimen J 32758, fig. 34) have a high-oval section. The whorl section is oxycone at the diameter of about 250 mm in J 30508 (not figured) and remains to be so in the holotype to the diameter of 400 mm. The umbilical wall is vertical on the innermost preserved whorl of J 32757 (fig. 33). It is less and less inclined in the holotype from the umbilical width of 25 mm on. J 32758 (fig. 34) is ribbed to the end at the diameter of 213 mm with three secondary ribs per primary rib. There are 32 primary ribs on the last whorl of this specimen, and the umbilical width is 46 mm at the end of the last whorl. In the holotype, the last primary ribs are visible at the umbilical width of about 40 mm at most. The section at the end of the last whorl of the holotype (fig. 32) and of J 32757 (fig. 33) is ellipsoidal. The peristome of the holotype is simple (fig. 31). The umbilical suture line of the holotype shows a conspicuous egression on the last whorl. This is 1.3 at the diameter of 540 mm.

Affinities: The size of *Ringsteadia magna* n.sp. is comparable to that of *Ringsteadia tenuiplexa* (Quenstedt, 1888) as figured on plate 111:3 by Quenstedt. The holotype of *Ringsteadia tenuiplexa* has a diameter of 444 mm. The specimen is complete with a simple peristome. The umbilical wall has a very similar ontogenetic variation in the two taxa. Another similarity is the egression of the umbilical suture line in *Ringsteadia tenuiplexa* (Quenstedt). The dimensions of the holotype of *Ringsteadia tenuiplexa* are almost the same as those of J 32757 as depicted here on figure 33. The strength of the primary ribs is also very similar on the inner whorls of both taxa. The main difference between *Ringsteadia magna* n.sp. and *Ringsteadia tenuiplexa* (Quenstedt) is in the ribbing on late ontogenetic stages. The last whorl of *Ringsteadia magna* n.sp. is smooth, whereas there are 17 simple, swollen ridges on the last whorl of the holotype of *Ringsteadia tenuiplexa.* In *Ringsteadia magna* n.sp. J 32758 (fig. 34), there are 32 weak primary ribs per whorl at the diameter of 213 mm, whereas there are only 23 primaries in the holotype of *Ringsteadia tenuiplexa* (Quenstedt) at the same ontogenetic stage. The principal difference between the two taxa is not morphologic, but temporal. Quenstedt (1888:995) stated that his *Ringsteadia tenuiplexa* is from the Weisser Jura γ (Kimmeridgian). *Ringsteadia magna* n.sp. is of the Bimammatum Subchron of the Late Oxfordian.

Material: 4 specimens: MNHB J 30508, J 32644, J 32757, J 32758.

Differential diagnosis: Ringsteadia magna n.sp. differs from *Ringsteadia tenuiplexa* (Quenstedt) in that its last whorl is smooth. At the corresponding late growth stage, where *Ringsteadia magna* is smooth, *Ringsteadia tenuiplexa* has 17 simple, swollen ridges on the whorl sides. The primary ribs on the inner whorls of *Ringsteadia tenuiplexa* are less numerous than in inner whorls of *Ringsteadia magna.*

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32644 Holotype	370	540	202	111	159	37	21	29	200 120	23 23
MNHB J 32757	340	450	155	-	158	34	-	35	-	-
MNHB J 30508	310	422	156	85	132	37	20	31	-	-
MNHB J 32758	Nu	213	96	47	46	45	22	22	213	32

Table 13. Dimensions of *Ringsteadia magna* n.sp.

Fig. 31. *Ringsteadia magna* n.sp., holotype, MNHB J 32644.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 6; lower Villi-

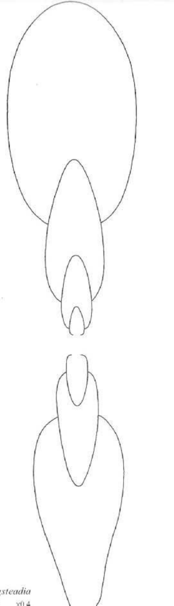


Fig. 32. Cross-section of *Ringsteadia magna* n.sp., MNHB J 32644. x0.4

Fig. 33. *Ringsteadia magna* n.sp., paratype, MNHB J 32757.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 9: lower Villigen Formation, found by C. Wyss. Coll. R. Gygi. ×0.4.

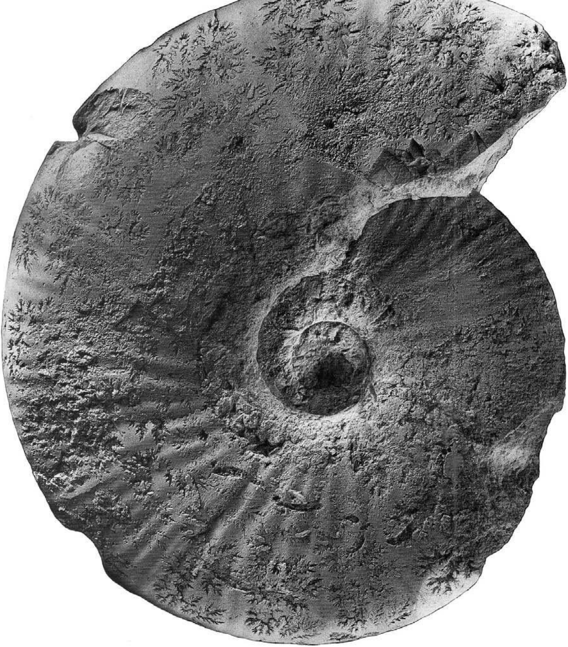


Fig. 34. *Ringsteadia magna* n.sp., paratype, MNHB J 32758.
Section RG 61, quarry southeast of the church at Vorder Rein, Rüfenach, Canton Aargau, bed no. 19: Crenularis Member.
Unlimited loan Ve. S. 110 of ETH Zürich. ×1.

Subfamily Aulacostephaninae Spath, 1924

Genus *Microbiplices* Arkell, 1936 [m]

Type species: Ammonites microbiplex Quenstedt (1887) [m]

Microbiplices microbiplex (Quenstedt, 1887) [m]
Fig. 35

1966 *Microbiplices microbiplex* (Quenstedt) – Enay, p. 567, fig. 156/2a–b, pl. 40:3, with synonymy.

Holotype: University of Tübingen, Museum für Geologie und Paläontologie, plate 94:36 in Quenstedt (1887).

Type locality: Lochengründle near Balingen, southern Germany.

Type horizon: Weisser Jura α.

Description: The glauconitic, carbonate internal mould of MNHB J 32772 (fig. 35) is septate to the diameter of 17 mm. Four fifths of the last whorl are occupied by the body chamber that seems to be nearly complete, because the last secondary ribs are approximated. The specimen is probably adult. The dimensions are: Dm 30 mm, Wh: 11 mm (0.37), Wt: 11 mm (0.37), Um: 11 mm (0.37). The section of the last whorl is circular. The number of primary ribs is eleven on the last half whorl. The primary ribs are radial, high and sharp. They split just above half the whorl height into two strong secondary ribs.

Affinities: The size, dimensions and the ribbing of MNHB J 32772 correspond very well with the holotype and also with the specimen FSL 75.769 as figured by Enay (1966, pl. 40:3). Septal suture lines are drawn at the end of the last whorl in the lateral view of the holotype in Quenstedt (1887, pl. 94:36). In the siphonal view of the holotype, no septal corrugations are shown on the two fracture surfaces of the last whorl. But on the fracture surface of the before last whorl, septal corrugations are represented. The last half whorl of the holotype may then be part of the body chamber.

Material: 1 specimen: MNHB J 32772.

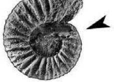


Fig. 35. *Microbiplices microbiplex* (Quenstedt), MNHB J 32772.
Section RG 65, old quarry of cement works, Würenlingen, Canton Aargau, bed no. 255: Crenularis Member.
Coll. R. Gygi. ×1.

Family Aspidoceratidae Zittel 1895

Subfamily Euaspidoceratinae Spath 1931

Genus *Clambites* Rollier 1922

Type species: Ammonites clambus Oppel 1963.

Clambites aequicosta (Quenstedt 1887)
Fig. 36

* 1887 *Ammonites perarmatus aequicosta* – Quenstedt, p. 890, pl. 96:5.

Holotype: University of Tübingen, Geological Museum, plate 96:5 in Quenstedt (1887 in 1887/88).

Type locality: Lochen near Balingen, southern Germany.

Type horizon: Weisser Jura α β.

Dimensions of MNHB J 24387: Dm: 134 mm, Wh: 44 mm (33%), Wt: 36 mm (27%), Um: 49 mm (37%).

Fig. 36. *Clambites aequicosta* (Quenstedt), MNHB J 24387.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 3: lower Villigen Formation.
Coll. A. Villa. ×1.

Description: The carbonate internal mould of MNHB J 24387 is septate to the diameter of 89 mm. Five eighths of the last whorl are occupied by the body chamber. The section of the last whorl is oval. The ribs on the visible part of the inner whorl are distinct and radial. They begin with a node above the vertical umbilical wall and end with a node on the siphonal margin. The ribs fade away on the external part of the whorl sides on the last third of whorl of the body chamber. The ribs are approximated at the broken end of the body chamber. The figured specimen is therefore adult and nearly complete. The umbilical row of nodes continues to the end of the body chamber. The siphonal row of nodes fades away at the end of the phragmocone. There were apparently hollow spines above the nodes.

Affinities: The diameter of the phragmocone of the described specimen MNHB J 24387 is with 89 mm greater than that of the holotype. The phragmocone of the holotype has, as measured on Quenstedt's plate 96:5, a diameter of 60 mm. The holotype has a somewhat wider umbilicus than that of the specimen figured here. Quenstedt's holotype was assigned by the Deutsche Subkommission für Jura-Stratigraphie (1973:32) to *Clambites schwabi* (Oppel, 1863). The holotype of Oppel's taxon, to judge of the original figure, has no internal nodes and a flattened siphonal side.

Material: 1 specimen: MNHB J 24387.

Description: The carbonate internal mould of MNHB J 32773 has a diameter of 482 mm and is septate to the diameter of 315 mm. Almost the whole last whorl is occupied by the body chamber that is nearly complete. The last primary rib is subdued and has a forward inclination. The peristome is broken off. The sides of the inner whorls are convex, and the umbilical wall is well-rounded. The last whorl has a thick-oval section. The primary ribs of the inner whorls begin at the umbilical suture line. They are strong, straight and radial. On the last whorl of the phragmocone and on the body chamber, the primary ribs begin on the umbilical wall and leave the lower part of the wall smooth. No secondary ribs are visible. The primary ribs of the last whorl are distant, high ridges. The last whorl covers the preceding one by 20%.

Affinities: MNHB J 32773 is somewhat larger than the nearly complete lectotype that has a diameter of 450 mm. The ribbing of both specimens is very similar except at the end of the last whorl of the lectotype. The last ribs of the lectotype are enhanced at the umbilical margin. Therefore, the section of the lectotype at the end of the last whorl, as seen above the ribs, has a wide and only slightly convex siphonal side. The whorl section near the aperture of the lectotype is very similar to that of specimen no. 40366 in figure 22a given by Hantzpergue (1989). The inner whorls of J 32773 are more densely ribbed than those of the lectotype (fig. 40). This and the different section at the end of the last whorls of J 32773 and of the lectotype are the reasons why J 32773 is identified as cf. *gigantoplex*. The ribbing of the lectotype is irregular to some extent (fig. 40).

Material: 1 specimen: MNHB J 32773.

3.1.2 Perisphinctids of the Wangen and Küssaburg Members (Bimammatum Chron, Hauffianum Subchron, Late Oxfordian)

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Lithacosphinctes* Olóriz, 1978

Type species: Ammonites lictor evolutus Quenstedt, 1887 [M].

Lithacosphinctes cf. *gigantoplex* (Quenstedt, 1887) [M]
Fig. 37–40; table 14

1989 *Lithacosphinctes gigantoplex* (Quenstedt) – Hantzpergue, p. 119, text-fig. 22–24, text-fig. 32, text-fig. 125/3, pl. 6:a–c, with synonymy.

Lectotype: University of Tübingen, Museum für Geologie und Paläontologie, plate 102:4 in Quenstedt (1887 in 1887/88), designated by Hantzpergue (1989:119).

Type locality: Wasseralfingen, southern Germany.

Type horizon: Weisser Jura β.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32773	315	482	113	-	282	23	-	59	480	19
									400	19
									350	21
									300	24
									260	28
									220	34
									180	40
									160	41
									140	41
									120	40
									100	39
									50	35
Tübingen, lectotype	315	450	100	98	267	22	22	59	450	22
									400	22
									350	24
									300	24
									200	24
									150	25
									100	30
									60	35

Table 14. Dimensions of *Lithacosphinctes gigantoplex* (Quen stedt).

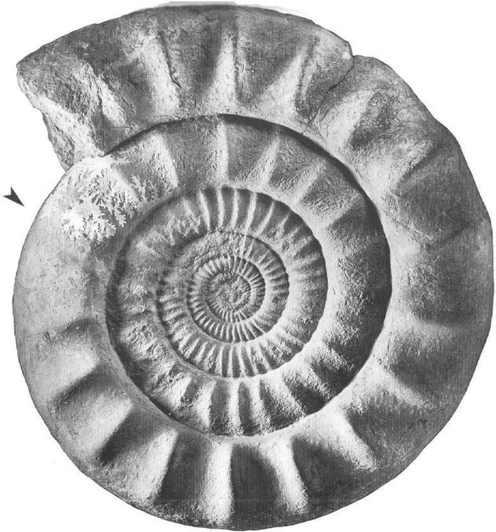


Fig. 37. *Lithacosphinctes* cf. *gigantoplex* (Quenstedt), MNHB J 32773.
The original label read: "Mittlerer Malm, Randen". To judge from the matrix of the steinkern, the specimen is from the upper Küssaburg Member of the Randen hills, Canton Schaffhausen. Unlimited loan of ETH Zürich. ×0.4.

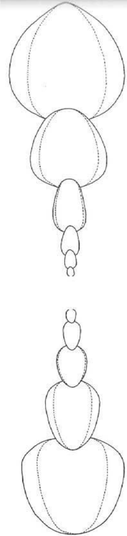


Fig. 38. Cross-section of *Lithacosphinctes* cf. *gigantoplex* (Quenstedt), MNHB J 32773. ×0.4.

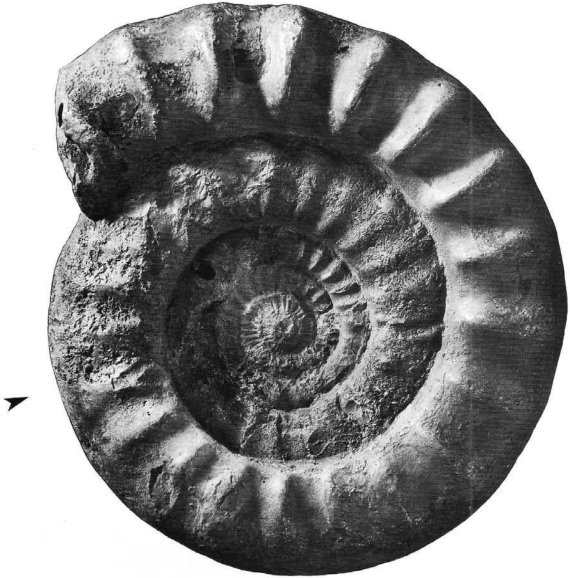


Fig. 39. *Lithacosphinctes gigantoplex* (Quenstedt), lectotype, Weisser Jura β, Wasseralfingen, southern Germany. Photograph by courtesy of H.P. Luterbacher, University of Tübingen, reproduction of pl. 102:4 in Quenstedt (1887 in 1887/88).

×0.4.

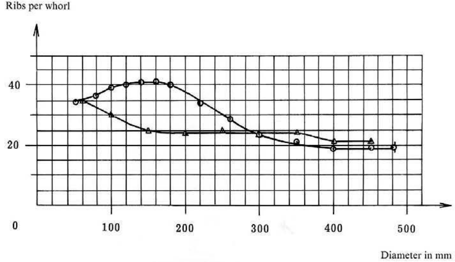


Fig. 40. Rib curves of *Lithacosphinctes gigantoplex* (Quenstedt).
Circles: MNHB J 32773;
triangles: lectotype.

Lithacosphinctes serotinus n.sp. [M]

Fig. 41–42; table 15

Synonymy and holotype: See page 24.

Description: The carbonate internal mould of MNHB J 32765 is septate to the diameter of 180 mm. The body chamber occupies almost exactly the whole last whorl. Part of the peristome is visible at the diameter of about 305 mm on the left side (fig. 41). The specimen is a complete adult. The section of the last whorl is oval (fig. 42). The umbilical wall of the last whorl touches the preceding whorl at an angle of only about 60°. The primary ribs of the inner whorls begin at the umbilical suture line. On the last whorl, the lower umbilical wall is smooth, and the primary ribs begin at the umbilical margin. The point of division is indistinct. It is at about half of the whorl height. The secondary ribs are fine and weak. There are up to eight secondaries per primary rib on the body chamber. The secondary ribs are preserved to the diameter of 210 mm and are no more visible at the diameter of 225 mm. The siphonal side of the last whorl is smooth. Distant and swollen, gerontic primary ribs appear only on the last half whorl.

Affinities: The dimensions and the ribbing of the paratype MNHB J 32765 agree well with the holotype J 32764 that is described on page 24.

Material: 2 specimens: MNHB J 32765, J 32766.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32765	180	279	75	61	132	27	22	47	305 110 80 50	19 48 49 42

Table 15. Dimensions of *Lithacosphinctes serotinus* n.sp.

Genus *Orthosphinctes* Schindewolf, 1925

Subgenus *Orthosphinctes* Schindewolf, 1925 [m]

Type species: Ammonites tiziani Oppel, 1863 [m].

Orthosphinctes (Orthosphinctes) sp.nov. aff. *danubiensis* Schlosser in Choffat (1893) [m]

Fig. 43–44; table 16

1893 *Perisphinctes* sp.nov. aff. *danubiensis* Schlosser – Choffat, p. 37, pl. 8:5.

Description: The carbonate internal mould of MNHB J 32774 has a diameter of 135 mm. No septal suture lines are visible, but the specimen seems to be a nearly complete adult, because the last two primary ribs are approximated, there is a prebuccal constriction, and because part of the peristome is preserved on the right side (reverse of the side visible in fig. 43). The specimen is diagenetically compressed. The primary ribs begin at the umbilical suture line. They are straight and radial except on part of the last whorl where they are proconcave. There are two to three secondary ribs per primary rib. The last whorl covers the preceding one only a little. The specimen is not preserved well enough to serve as holotype of a new species.

Affinities: The dimensions (except the whorl thickness) of MNHB J 32774 are very similar to those of the specimen as figured by Choffat (1893, pl. 8:5). The ribbing of Choffat's specimen is slightly denser than that of J 32774. The Swiss specimen is only a little larger than that from Portugal. The two forms are probably conspecific. They have nothing to do with *Ammonites (Perisphinctes) Danubiensis* Schlosser (1882, pl. 9:3) that is larger and above all much younger.

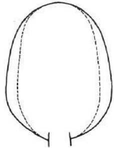


Fig. 42. Whorl section of *Lithacosphinctes serotinus* n.sp., MNHB J 32765. ×0.7.

Fig. 41. *Lithacosphinctes serotinus* n.sp., MNHB J 32765.
From between Laufen and Tieringen, southern Germany, β-Kalk.
Ex coll. L. Rollier, ETH Zürich, unlimited loan. ×0.7.

Fig. 43. *Orthosphinctes (Orthosphinctes)* n.sp. aff. *danubiensis* in Choffat (1893), MNHB J 32774.
Section RG 79, quarry at Tenggibuck, Neunkirch, Canton Schaffhausen, bed no. 22: Küssaburg Member.
Coll. R. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32774	?	135	41	-	63	30	-	47	135 100 30	47 45 36

Table 16. Dimensions of *Orthosphinctes (Orthosphinctes)* n.sp. aff. *danubiensis* in Choffat (1893).

Orthosphinctes (Orthosphinctes) suevicus (Siemiradzki, 1898: 238, pl. 24:35) from Weisser Jura β of southern Germany (*bimammatum* horizon according to Schweigert & Callomon, 1997:35) has an almost equal size as *Orthosphinctes (Orthosphinctes)* n.sp. aff. *danubiensis* in Choffat (1893). But the innermost whorls of Siemiradzki's taxon have a denser and prorsiradiate ribbing, whereas there are less primary ribs on its last whorl. Schweigert & Callomon (1997:35) assigned the taxon *suevicus* Siemiradzki to *Subnebrodites* and regarded it to be a macroconch. *Orthosphinctes (Pseudorthosphinctes) triplicatus albus* (Quenstedt) is larger with a probable maximum diameter of about 200 mm. The holotype of this taxon is septate to the diameter of 136 mm, but its ribbing is very similar to that of *Orthosphinctes (Orthosphinctes)* n.sp. aff. *danubiensis* in Choffat (1893).

Material: 1 specimen: MNHB J 32774.

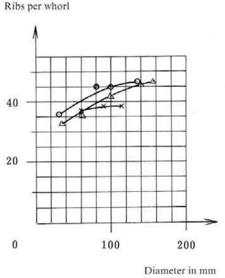


Fig. 44. Rib curve of *Orthosphinctes (Orthosphinctes)* n.sp. aff. *danubiensis* in Choffat (1893).
Circles: MNHB J 32774;
triangles: holotype of *Orthosphinctes (Pseudorthosphinctes) triplicatus albus* (Quenstedt);
crosses: *Orthosphinctes (Orthosphinctes) suevicus* (Siemiradzki).

Orthosphinctes (Orthosphinctes) cf. *mogosensis* (Choffat, 1893) [m]
Fig. 45–46; table 17

1893 *Perisphinctes Mogosensis* sp.nov. – Choffat, p. 50, pl. 12:5–8.
non 1930 *Perisphinctes Mogosensis* Choffat – Dorn, p. 165, pl. 28:4.

Lectotype: Plate 12:5 in Choffat (1893), designated by Enay (1966:517).

Type locality and section: Cabanas de Torres, Portugal.

Type horizon: Bed no. 12 of the section.

Description: The diagenetically compressed carbonate internal mould of MNHB J 32775 shows traces of septal suture lines to the diameter of 65 mm. A third of the last whorl seems to be occupied by the body chamber. The primary ribs on the preserved half of the body chamber are straight and radial. On the phragmocone, the primary ribs swing back on the umbilical wall and then bend forward on the whorl sides. The primary ribs split at about 60% of the whorl height into two secondary ribs. Intercalated secondary ribs are common. The secondary ribs of the phragmocone form a proconvex arc on the siphonal side, but on the body chamber they have the same direction as the primary ribs. The last whorl covers the preceding one only slightly.

Affinities: The excellent quality of the photographs on the plates by Choffat (1893) make it possible to conclude that about three quarters of the last whorl of the lectotype of *Orthosphinctes (Orthosphinctes) mogosensis* (Choffat) are occupied by the body chamber. If this be the case, then the phragmocone of the lectotype would have a diameter of about 60 mm. The dimensions of MNHB J 32775 compare well with this and with the dimensions of the lectotype as given by Choffat (1893:50). The ribbing of J 32775 is also similar to that of the lectotype. *Perisphinctes Mogosensis* Dorn (1930, pl. 28:4) is probably larger, has a wider umbilicus and has somewhat less ribs per whorl. Dorn (1930:166) stated that his specimen was from the Hypselum Zone, whereas J 32775 is of the Hauffianum Subchron of the Bimammatum Chron. The irregular ribbing of J 32775 is the reason why the specimen is identified as cf. *mogosensis*.

Material: 1 specimen: MNHB J 32775.

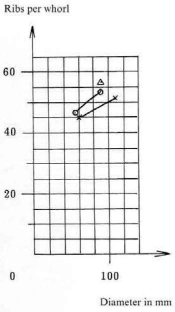


Fig. 46. Rib curve of *Orthosphinctes (Orthosphinctes)* cf. *mogosensis* (Choffat).
Circles: MNHB J 32775;
triangle: lectotype in Choffat (1893, pl. 12:5);
crosses: *Perisphinctes Mogosensis* Dorn (1930, pl. 28:4).

Fig. 45. *Orthosphinctes (Orthosphinctes)* cf. *mogosensis* (Choffat), MNHB J 32775.
Section RG 57, quarry at Laufacher 100 m southeast of the northern entrance to the Bözberg railway tunnel, Zeihen, Canton Aargau, bed no. 38: upper Wangen Member.
Coll. R. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32775	?	83	27	–	38	33	–	46	88 55	53 47

Table 17. Dimensions of *Orthosphinctes (Orthosphinctes)* cf. *mogosensis* (Choffat).

3.1.3 Perisphinctaceans of the Knollen Bed, Letzi and Wangental Member (latest Bimammatum Chron, Late Oxfordian, and Planula Chron, Early Kimmeridgian)

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Lithacosphinctes* Olóriz, 1978

Type species: Ammonites lictor evolutus Quenstedt, 1887 [M].

Lithacosphinctes cf. *evolutus* (Quenstedt, 1887) [M]
Fig. 47–48; table 18

1982 *Orthosphinctes* (M. *Lithacosphinctes*) *evolutus* (Quenstedt) – Atrops, p. 125, text-fig. 22, pl. 25:1–2, 26:1, pl. 27:1, pl. 28:1, pl. 29:1, pl. 45:1, with synonymy.

1985 *Orthosphinctes (Lithacosphinctes) evolutus* (Quenstedt) – Schairer, p. 9, text-fig. 2, pl. 2:4; pl. 3:2–3.

Holotype: University of Tübingen, Museum für Geologie und Paläontologie, plate 105:2 in Quenstedt (1887 in 1887/88).

Type locality: Wasseralfingen, southern Germany.

Type horizon: Weisser Jura β.

Description: The carbonate internal mould of MNHB J 32776 is septate to the diameter of 140 mm. One fourth of the last whorl is occupied by the body chamber. The section of the last whorl is oval. The straight and radial primary ribs begin at the umbilical suture line. They split at about 70% of the whorl height into two to three secondary ribs on the phragmocone. On the body chamber, the point of division is indistinct and lower down than 50% of the whorl height. There are five weak secondary ribs per primary rib on the body chamber. The secondary ribs of the phragmocone have a slightly stronger forward inclination than the primaries and form a broad proconvex arc on the siphonal side. The last whorl covers the preceding one by 38%.

Affinities: The whorl section and the style of ribbing of J 32776 are very similar to the holotype. But the phragmocone of MNHB J 32776 is considerably smaller than that of the holotype. The umbilicus of J 32776 is somewhat narrower than that of the holotype at the corresponding growth stage.

Material: 1 specimen: MNHB J 32776.

Fig. 47. *Lithacosphinctes* cf. *evolutus* (Quenstedt), MNHB J 32776.
Section RG 90 at the railway station of Leipferdingen, southern Germany, bed no. 7: uppermost Wangental Member.
Coll. R. Gygi. ×1.

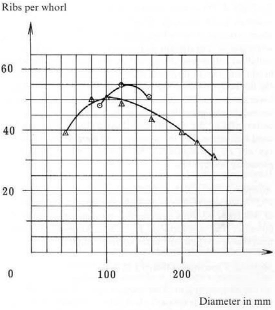


Fig. 48. Rib curves of *Lithacosphinctes* cf. *evolutus* (Quenstedt), MNHB J 32776 (circles), and of *Lithacosphinctes evolutus* (Quenstedt), holotype (triangles).

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
Holotype, Tübingen	167	242	57	-	132	24	-	55	242 220 200 160 120 100 80 50	31 36 39 43 48 52 50 39
MNHB J 32776	140	157	52	-	67	33	-	43	157 120 90	51 55 48

Table 18. Dimensions of *Lithacosphinctes evolutus* (Quenstedt), holotype, and *Lithacosphinctes* cf. *evolutus* (Quenstedt), MNHB J 32776.

Lithacosphinctes aff. *grandiplex* (Quenstedt, 1887) [M]

Fig. 49, 51; table 19

1989 *Subdiscosphinctes grandiplex* (Quenstedt) – Hantzpergue, p. 87, text-fig. 7–9, text-fig. 124, pl. 1:a–c, with synonymy.

Lectotype: University of Tübingen, Museum für Geologie und Paläontologie, plate 102:1 in Quenstedt (1887 in 1887/88).

Type locality: Ahlsberg near Pfullingen, southern Germany.

Type horizon: Weisser Jura β.

Description: The carbonate internal mould of MNHB J 27256 is septate to the diameter of 205 mm. Three fourths of the last whorl are occupied by the body chamber. The body chamber seems to be complete even though the peristome is not preserved, because the last two ribs are approximated, and because the last rib is subdued. 24 radial primary ribs can be counted on the last whorl. No secondary ribs are visible. The siphonal side of the last whorl is smooth. The last whorl covers the preceding one by 25%.

Affinities: The maximum diameter of J 27256 is with ca. 330 mm comparable to the 392 mm of the lectotype. The umbilicus of both specimens is relatively narrow for a large *Lithacosphinctes:* At the diameter of 286 mm it is 49% in J 27256 and only 43% at the same diameter in the lectotype. Both forms have markedly compressed inner whorls, and their style of ribbing is similar. However, J 27256 has 24 primary ribs on the last whorl as compared with 17 in the lectotype. The greatest whorl thickness of the body chamber is 25% in J 27256 as compared with ca. 22% in the lectotype. The lectotype can be distinguished from all other "species" of *Lithacosphinctes* by its very densely ribbed inner whorls. The inner whorls of J 27256 are not preserved. Therefore, the question must remain open whether this specimen is conspecific with *Lithacosphinctes grandiplex* (Quenstedt) or not.

Material: 1 specimen: MNHB J 27256.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
Tübingen, lectotype	254	382	100	~85	200	26	~22	52	390 350 300 280 260 240 220 200 160 140 120 100	17 17 18 20 22 23 24 30 46 60 74 79
MNHB J 27256	205	286	73	71	141	25	25	49	310 280 260 200	24 24 25 32?

Table 19. Dimensions of *Lithacosphinctes grandiplex* (Quenstedt).

Fig. 49. *Lithacosphinctes* aff. *grandiplex* (Quenstedt), MNHB J 27256.
Section RG 70, large quarry, Mellikon, Canton Aargau, to judge from the matrix probably bed no. 114: uppermost Letzi Member.
Coll. A. Villa. ×0.7.

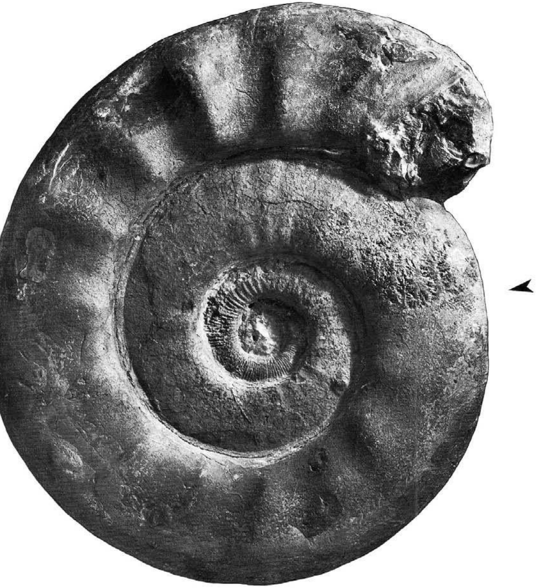


Fig. 50. *Lithacosphinctes grandiplex* (Quenstedt), lectotype.
Weisser Jura β, Ahlsberg, southern Germany.
Photograph by courtesy of H.P. Luterbacher, University of Tübingen, reproduction of pl. 102:1 in Quenstedt (1887 in 1887/88).
×0.5.

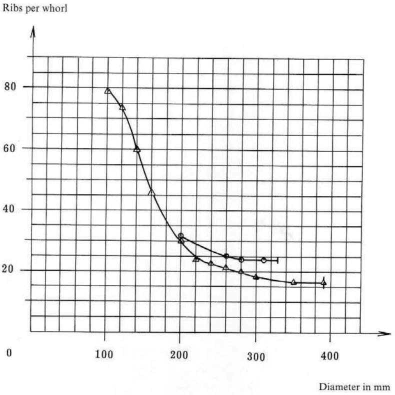


Fig. 51. Rib curves of *Lithacosphinctes* aff. *grandiplex* (Quenstedt), NMHB J 27256 (circles), and of *Lithacosphinctes grandiplex* (Quenstedt), lectotype (triangles).

Lithacosphinctes aff. *gigantoplex* (Quenstedt, 1887) [M]
Fig. 52–53; table 20

Synonymy and lectotype: See page 46.

Description: The carbonate internal mould of MNHB J 24361 has a diameter of 380 mm and is septate to the diameter of 260 mm. The body chamber occupies three fourths of the last whorl. The peristome is not preserved. Nevertheless, the body chamber must be nearly complete, because the whorl thickness greatly diminishes at the end of the last whorl, and because the last three ribs are approximated. The last rib is attenuated and has an abnormal forward inclination. The section of the body chamber is variable because of diagenetic deformation, but it is depressed in the greater part of the body chamber. The primary ribs are strong and radial. No secondary ribs are visible on the last whorl that has a smooth siphonal side.

Affinities: MNHB J 24361 has an estimated maximum diameter of about 400 mm and is therefore not much smaller than the lectotype. The whorl section of the Swiss specimen is also similar to that of the lectotype, and so is the preserved part of the ribbing. But the umbilicus of J 24361 is with 53% much narrower than that of the lectotype (59%). *Perisphinctes (Arisphinctes) westburyensis* Arkell (1947:368, text-fig. 131) is a similar form that occurs in England. It has a maximum diameter of about 450 mm like the lectotype of *Lithacosphinctes gigantoplex* (Quenstedt), but its umbilicus is with 55% (measured on the photograph) narrower than that of Quenstedt's taxon. The rib curve as drawn after Arkell's figures on page 368 is also different (fig. 52).

Material: 1 specimen: MNHB J 24361.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24361	260	380	94	104	200	25	27	53	400 380 360 300 260	24 24 25 25 25

Table 20. Dimensions of *Lithacosphinctes* aff. *gigantoplex* (Quenstedt).

Fig. 52. *Lithacosphinctes* aff. *gigantoplex* (Quenstedt), MNHB J 24361.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 117: uppermost Letzi Member.
Coll. A. Villa. ×0.5.

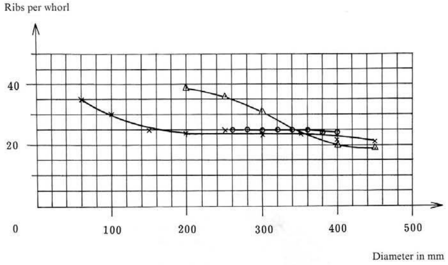


Fig. 53. Rib curves of *Lithacosphinctes gigantoplex* (Quenstedt), lectotype (crosses), *Lithacosphinctes* aff. *gigantoplex* (Quenstedt), MNHB J 24361 (circles), and *Lithacosphinctes westburyensis* (Arkell) (triangles).

Genus *Orthosphinctes* Schindewolf, 1925

Subgenus *Orthosphinctes* Schindewolf, 1925 [m]

Type species: Ammonites tiziani Oppel, 1863 [m].

Orthosphinctes (*Orthosphinctes*?) cf. *mogosensis* (Choffat, 1893) [m]
Fig. 54–55; table 21

Synonymy and type: See page 52.

Description: The slightly glauconitic, carbonate internal mould of MNHB J 32777 is septate to the diameter of 65 mm. The preserved part of the body chamber occupies seven eighths of the last whorl, but a trace of the umbilical suture line of the last whorl continues to the end of the phragmocone on the preceding whorl. The complete body chamber must then have occupied the entire last whorl to a diameter of almost 110 mm. The section of the body chamber is high-oval. The primary ribs of the last whorl begin on the umbilical margin where they swing back. The umbilical wall is smooth. On the whorl sides the primary ribs are slightly proconcave. Most of them split at 70% of the whorl height into two secondary ribs. The primary ribs have a forward inclination of 15–18°. Three primaries are unsplit on the last whorl. The secondary ribs form a proconvex arc on the siphonal side. They are not attenuated along the siphuncle. The last whorl covers the preceding one by 25%.

Affinities: The dimensions and the whorl section of MNHB J 32777 compare well with those of the lectotype of *Perisphinctes Mogosensis* in Choffat (1893:50, pl. 12:5b). But the ribbing of the Swiss specimen is different: Some primary ribs of J 32777 are unsplit, and there are never more than two secondary ribs per primary. There are often three secondary ribs per primary in the lectotype. The primary ribs of J 32777 have a stronger forward inclination than those of the lectotype. The forward inclination of the secondary ribs in the lectotype is less than that in J 32777. There is only one constriction on the last whorl of the lectotype as compared with three on the last whorl of J 32777. The last constriction of J 32777 is just visible on the umbilical margin at the end of the last whorl in figure 54. The ribbing of the lectotype is slightly denser than that of J 32777 (compare fig. 55 with 46).

Material: 1 specimen: MNHB J 32777.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32777	65	105	33	-	49	31	-	47	100 60 28	52 44 35

Table 21. Dimensions of *Orthosphinctes (Orthosphinctes)* cf. *mogosensis* (Choffat).

Fig. 54. *Orthosphinctes (Orthosphinctes)* cf. *mogosensis* (Choffat), MNHB J 32777.
Section RG 91, ooze of the Danube river, Immendingen, southern Germany, bed no. 12: Knollen Bed.
Coll. R. Gygi. ×1.

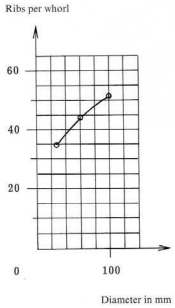


Fig. 55. Rib curve of *Orthosphinctes (Orthosphinctes)* cf. *mogosensis* (Choffat), MNHB J 32777.

Orthosphinctes (*Orthosphinctes*?) aff. *mogosensis*
(Choffat, 1893) [m]
Fig. 56–57; table 22

Synonymy and type: See page 52.

Description: The carbonate internal mould of MNHB J 32778 with rare and small glauconite pellets is septate to the diameter of 55 mm. Four fifths of the last whorl are occupied by the body chamber. The section of the body chamber is oval. The primary ribs on the phragmocone are straight and almost radial. They grow progressively proconcave on the body chamber and there lean slightly backward. The lower umbilical wall is smooth on the body chamber. The primary ribs split into two secondary ribs at 75% of the whorl height. There are two intercalated secondary ribs on the last fourth whorl of the body chamber. The secondary ribs have a stronger forward inclination than the primaries and form a proconvex arc on the siphonal side.

Affinities: The dimensions, the whorl section and the style of ribbing of MNHB J 32778 are similar to the lectotype in Choffat (1893, pl. 12:5). But the umbilicus of J 32778 is narrower than that of the lectotype. Another difference are the primary ribs on the body chamber of J 32778: They are much more proconcave than in the lectotype and lean somewhat backward, not forward as in the lectotype. The secondary ribs of J 32778 lean more forward than in the lectotype.

Material: 1 specimen: MNHB J 32778.

Fig. 56. *Orthosphinctes (Orthosphinctes)* aff. *mogosensis* (Choffat), MNHB J 32778.
Lindhammer, Bargen, Canton Schaffhausen: β-Kalke. Glauconite in the matrix indicates that the specimen is from the Knollen Bed.
Ex coll. of ETH Zürich, unlimited loan. ×1.

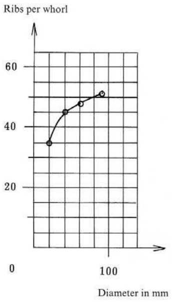


Fig. 57. Rib curve of *Orthosphinctes (Orthosphinctes)* aff. *mogosensis* (Choffat), MNHB J 32778.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32778	55	88	30	24.5	38	34	28	43	90 60 40 20	52 48 45 35

Table 22. Dimensions of *Orthosphinctes (Orthosphinctes)* aff. *mogosensis* (Choffat).

Orthosphinctes (*Orthosphinctes*?) n.sp.

Fig. 58–59; table 23

Description: The carbonate internal mould of MNHB J 32779 is septate to the diameter of 32 mm. The body chamber occupies seven eighths of the last whorl and is complete with the peristome and part of a lappet. The whorl section is trapezoidal with marked umbilical and siphonal margins and an only slightly arcuate siphonal side. The whorl sides converge so little that the whorl section is almost rectangular. The primary ribs on the phragmocone begin at the umbilical suture line and are radial on the umbilical wall. The lower umbilical wall of the body chamber is smooth. On the whorl sides the primaries are straight and lean 15° forward. They split at about 65% of the whorl height into two to three weak secondary ribs. The secondary ribs bend a little more forward than the primaries and form a proconvex arc on the siphonal side. The last whorl covers the preceding one by ca. 20%.

Affinities: Orthosphinctes (*Orthosphinctes*?) n.sp. J 32779 resembles to some extent *Orthosphinctes (Praeataxioceras)* sp. B

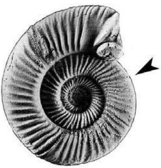


Fig. 58. *Orthosphinctes (Orthosphinctes)* n.sp., MNHB J 32779.
β-Kalke, Randen, Canton Schaffhausen.
Ex coll. of ETH Zürich, unlimited loan. ×1.

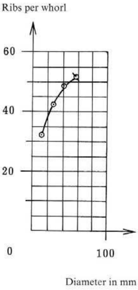


Fig. 59. Rib curve of *Orthosphinctes (Orthosphinctes)* n.sp., MNHB J 32779.

J 24376 (fig. 24). Both are complete adults at nearly the same diameter and have almost identical dimensions. The primary ribs split in the same style and at the same height of the whorl.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32779	32	56	17	14	27	31	25	48	56 40 25 10	52 48 42 32

Table 23. Dimensions of *Orthosphinctes (Orthosphinctes)* n.sp.

Orthosphinctes (*Orthosphinctes*?) n.sp. differs from *Orthosphinctes (Praeataxioceras)* sp. B in the following respects: It has a trapezoidal instead of an elliptical whorl section. The primary ribs have a stronger forward inclination. They begin on the body chamber only on the umbilical margin. In *Orthosphinctes (Praeataxioceras)* sp. B the primary ribs begin at the umbilical suture line to the end of the body chamber. The rib curve of *Orthosphinctes* (*Orthosphinctes*?) n.sp. rises steeply (fig. 59), whereas it is horizontal in *Orthosphinctes (Praeataxioceras)* sp. B (see table 10). There is probably a difference in age between the two taxa.

There is some resemblance between *Orthosphinctes* (*Orthosphinctes*?) n.sp. and *Ammonites polygyratus* in Quenstedt (1887 in 1887/88, pl. 100:1) which, according to Quenstedt, is also from Weisser Jura β (Bimammatum Zone according to a letter by G. Schweigert dated 26/1/2001). The specimen as figured by Quenstedt has almost the same diameter and seems to be complete. However, it has less ribs on the last whorl and a narrower umbilicus than *Orthosphinctes* (*Orthosphinctes*?) n.sp. *Perisphinctes obliqueplicatus* Waagen in Simionescu (1907, pl. 1:5) has only two secondary ribs per primary and a different whorl section (Simionescu, 1907, text-fig. 5).

Material: 1 specimen: MNHB J 32779.

Family Simoceratidae Spath, 1924

Subfamily Idoceratinae Spath, 1924

Genus *Subnebrodites* Spath, 1925

Type species: Ammonites planula Quenstedt, 1887.

Remark: Spath (1925:129) based his new genus *Subnebrodites* on figure 2 of plate 102 in Quenstedt (1887 in 1887/88). It cannot be ascertained whether Quenstedt's taxon is conspecific with *Ammonites planula* (Hehl) in Zieten (1830), because the publication by Zieten (1830) and above all the type of *Ammonites planula* (Hehl) in Zieten were not seen by the author. The problem can therefore not be solved here.

Subnebrodites planula (Quenstedt 1887)
Fig. 60; table 24

v 2000 *Subnebrodites planula* (Quenstedt) – Gygi, p. 93, pl. 11:5, with synonymy.

Type: University of Tübingen, Museum für Geologie und Paläontologie, plate 108:2 in Quenstedt (1887 in 1887/88).

Type locality: Wasseralfingen, southern Germany.

Type horizon: Weisser Jura β.

Description: The carbonate internal mould of MNHB J 27403 is septate to the diameter of 39 mm. The entire last whorl is occupied by the body chamber. The peristome is not preserved. Nevertheless, the specimen seems to be adult because of deep constriction near the end of the body chamber and because of two enhanced ribs after the constriction. The whorl of the phragmocone are filled with sparite and could only b prepared imperfectly. The section of the body chamber is el lipsoidal. The primary ribs begin at the umbilical suture line They are strong and straight. Most of them are radial. The split at 65% of the whorl height into two secondary ribs. Th secondaries are bent forward. They are interrrupted along th siphonal line by a smooth band (fig. 60b).

Affinities: MNHB J 27403 is considerably smaller than th specimen as figured by Quenstedt (1887 in 1887/88, pl. 108:2 but it has very similar dimensions at the corresponding growt stage. The secondary ribs of Quenstedt's specimen are nc bent forward at the growth stage corresponding to J 2740. It is uncertain whether J 27403 is conspecific with *Idoceras pla nula* (Hehl) in Ziegler (1959:1, fig. 9).

Material: 1 specimen: MNHB J 27403.

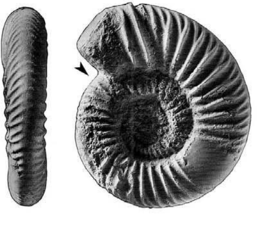


Fig. 60. *Subnebrodites planula* (Quenstedt, non Hehl in Zi ten), MNHB J 27403.
Section RG 82c below Steimürlichopf, in Churz Tal, Siblingen, Cant Schaffhausen, bed no. 139: lower Wangental Member.
Coll. R. Gygi.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whc	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	
MNHB J 27403	39	68	20.5	15.4	30.5	30	23	45	68	3

Table 24. Dimensions of *Subnebrodites planula* (Quenstedt).

Subnebrodites cf. *schroederi* (Wegele, 1929)

Fig. 61; table 25

cf. v 2000 *Subnebrodites schroederi* (Wegele) – Gygi, p. 93, pl. 13:4, with synonymy.

Lectotype: Plate 9:6 in Wegele (1929) as designated by Zeiss (1981:433).

Type locality: Road to Gelber Berg, Heidenheim, Franconia, southern Germany.

Type horizon: Planula Zone.

Description: The carbonate internal mould of MNHB J 24366 is septate to the diameter of 39 mm. Half of the last whorl is occupied by the body chamber. The whorl section is ellipsoidal. The primary ribs of the inner whorls are straight and radial. From the beginning of the last preserved whorl they are proconcave. They split at 67% of the whorl height into two secondary ribs. The secondaries bend forward and are interrupted at the siphonal side along a narrow smooth band.

Affinities: The specimen MNHB J 24366 resembles in its narrow umbilicus to the lectotype of *Subnebrodites schroederi*. But the ribbing of J 24366 is looser than that of the lectotype, and it has no unsplit ribs. The Swiss specimen is also considerably smaller than the lectotype. It is similar to *Subnebrodites schroederi* (Wegele) as figured in Gygi (2000a, pl. 13:4).

Material: 1 specimen: MNHB J 24366.

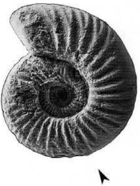


Fig. 61. *Subnebrodites* cf. *schroederi* (Wegele), MNHB J 24366.
Section RG 70, large quarry, Mellikon, Canton Aargau; Letzi Member.
Coll. E. von Braun. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24366	39	46.3	16.7	10	16.8	36	22	36	53 40 20	33 34 34

Table 25. Dimensions of *Subnebrodites* cf. *schroederi* (Wegele).

Subnebrodites minutus (Dieterich, 1940)

Fig. 62; table 26

1989 *Idoceras (Subnebrodites) minutum* (Dieterich) – Schairer, p. 105, table 5, text-fig. 5, pl. 8:1–14, with synonymy.

Lectotype: Plate 2:4 in Dieterich (1940) as designated by Zeiss (1981:433).

Type locality: Donzdorf, southern Germany.

Type horizon: Weisser Jura Mittel-β.

Description: The carbonate internal mould of MNHB J 27312 is septate to the diameter of 33 mm. Half of the last whorl is occupied by the body chamber. The whorl section is ellipsoidal. The primary ribs begin on the body chamber at the umbilical margin and there leave the lower umbilical wall smooth. They are straight and have a forward inclination of about 10°. The primary ribs split at 68% of the whorl height into two secondary ribs, but there are also some unsplit primary ribs. The secondary ribs bend forward and form a proconvex arc at the siphonal side. They are attenuated along the siphonal side. Only one pair of secondary ribs is entirely interrupted above the siphuncle at the diameter of 36 mm.

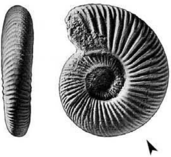


Fig. 62. *Subnebrodites minutus* (Dieterich), MNHB J 27312.
Section RG 82c below Steimürlichopf, in Churz Tal, Siblingen, Canton Schaffhausen, bed no. 137: lower Wangental Member.
Coll. R. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 27312	33	45	17	11	16	38	24	36	47 20	45 43

Table 26. Dimensions of *Subnebrodites minutus* (Dieterich).

Affinities: The dimensions of MNHB J 27312 compare well with those given by Dieterich (1940:34). In the syntypes cited by Dieterich, there are 41–54 primary ribs on the last whorl. 45 primary ribs were counted on the last whorl of J 27312. Because only one pair of secondary ribs is interrupted at the siphonal side of J 27312, the question arises whether J 27312 can be assigned to the genus *Subnebrodites* at all. Dieterich (1940:33) pointed out the same problem, but he stated on page

34 that the secondary ribs in his new taxon often formed a proconvex arc at the siphonal side as is the case in J 27312. Ziegler (1959:30) stated that the secondary ribs of the material examined by him were as a rule only attenuated siphonally. This is confirmed by the figures 1a and 1c as published by Zeiss (1981). Therefore, J 27312 is identified as *Subnebrodites minutus* (Dieterich) although none of its secondary ribs alternate at the siphonal side as was observed by Dieterich (1940:33) and by Ziegler (1959:30). It could be that J 27312 is an ancestral representative of the taxon, because it was found near the base of the Wangental Member (bed no. 137 of section RG 82c, see Gygi, 1969, pl. 16). G. Schweigert in a letter dated 26/1/2001 was of the opinion that J 27312 is a juvenile *Subnebrodites planula* (Hehl in Zieten).

Material: 1 specimen: MNHB J 27312.

Family Aulacostephanidae Spath, 1924

Subfamily Aulacostephaninae Spath, 1924

Genus *Rasenioides* Schindewolf, 1925

Type species: Nautilus striolaris Reinecke.

Rasenioides transitorius (Schindewolf, 1926)
Fig. 63; table 27

1961 *Rasenia (Rasenioides) transitoria* (Schindewolf) – Geyer, p. 111, pl. 1:6, with synonymy.

Holotype: Plate 19:3 in Schindewolf (1926).

Type locality: Burgfelden, Württemberg, southern Germany.

Type horizon: Weisser Jura γ.

Description: The carbonate internal mould of MNHB J 32780 is septate to the diameter of 22 mm. The last two septa are approximated. One third of the last whorl is occupied by the body chamber. The section of the last whorl is trapezoidal as drawn by Geyer (1961, fig. 125k). The primary ribs on the body chamber are short, proconcave and have a slight forward inclination. They begin at the umbilical margin. The lower part of the umbilical wall is smooth. The primary ribs split at about half the whorl height into three and occasionally into four strong secondary ribs that are not attenuated at the siphonal side. The secondary ribs, unlike the primaries, are radial.

Fig. 63. *Rasenioides transitorius* (Schindewolf), MNHB J 32780.
Section RG 90, quarry at railway station of Leipferdingen, southern Germany, bed no. 7: uppermost Wangental Member.
Coll. R. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32780	22	28.3	12	12	8.3	42	42	29	28	28

Table 27. Dimensions of *Rasenioides transitorius* (Schindewolf).

Affinities: The size of MNHB J 32780 is somewhat inferior to that of the holotype that was figured by Schindewolf (1926, pl. 19:3) at twice the natural size. The umbilicus of the holotype is narrower than that of J 32780. The primary ribs of the holotype split into four secondary ribs. J 32780 is somewhat older than the holotype. This may be the cause of these differences.

Material: 1 specimen: MNHB J 32780.

Family Aspidoceratidae Zittel, 1895

Subfamily Physodoceratinae Schindewolf, 1925

Genus *Sutneria* Zittel, 1884

Subgenus *Sutneria* Zittel, 1884

Type species: Nautilus platynotus Reinecke.

Remark: According to Schweigert (1997; 1998), the genus *Sutneria* is assigned to the subfamily Physodoceratinae Schindewolf, 1925.

Fig. 64. *Sutneria (Sutneria) galar* (Oppel), MNHB J 32809.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 114: uppermost Letzi Member.
Coll. R. Gygi. ×2.

Sutneria (Sutneria) galar (Oppel, 1863)
Fig. 64

v 2000a *Sutneria (Sutneria) galar galar* (Oppel) – Gygi, p. 97, pl. 13:3, with synonymy.

Lectotype: Plate 67:5 in Oppel (1863) as designated by Barthel (1959:59).

Type locality: Thalmässing, Franconia, southern Germany.

Type horizon: Zone of *Ammonites tenuilobatus.*

Description: The carbonate, slightly glauconitic internal mould of MNHB J 32809 is diagenetically deformed and cannot be measured exactly. It is septate to the diameter of about 10 mm. The last septa are not approximated. Half of the last whorl is occupied by the body chamber. A better representative of the taxon was described and figured by Gygi (2000a:97–98, pl. 13:3).

Material: 1 specimen: MNHB J 32809.

3.2 Perisphinctaceans of the Reuchenette Formation and time equivalents (Kimmeridgian)

3.2.1 Perisphinctaceans of the Reuchenette Formation

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Lithacosphinctes* Olóriz, 1978

Type species: Ammonites lictor evolutus Quenstedt, 1887 [M].

Fig. 65. *Lithacosphinctes pseudolictor* (Choffat), MNHB J 26517.
Section RG 21, quarry on Mt. Born, Olten, Canton Solothurn, not from *in situ*, collected from rubble (RG 240) blasted out of the lower Reuchenette Formation, beds no. 49–67 (see Gygi, 1969, pl. 18).
Coll. R. & S. Gygi. ×1.

Lithacosphinctes pseudolictor (Choffat, 1893) [M]

Fig. 65–66; table 28

1893 *Perisphinctes pseudolictor* sp.nov. – Choffat, p. 48, pl. 18:7–9.
1943 *Planites pseudolictor* (Choffat) – Butticaz, p. 21, pl. 3:1.
non 1961 *Lithacoceras (Lithacoceras) pseudolictor* (Choffat) – Geyer, p. 30, text-fig. 30, pl. 10:1.
non 1963 *Lithacoceras (Lithacoceras) pseudolictor* (Choffat) – Koerner, p. 365, text-fig. 60–61, pl. 23:2.

Lectotype: Plate 18:7 in Choffat (1893).

Type locality: Cabanas-de-Torres, Portugal.

Type horizon: Marnes d'Abadia.

Description: The carbonate internal mould of MNHB J 26517 with some small, pale-green glauconite pellets is septate to the diameter of 133 mm. One fourth of the last whorl is occupied by the body chamber. The whorl section is oval. The primary ribs begin at the umbilical suture line. They swing back on the umbilical margin. The primary ribs are radial and straight or only slightly proconcave on the sides of the inner whorls. On the last whorl the primaries become increasingly proconcave. The primaries split at about 50% of the whorl height into three secondary ribs at the diameter of 90 mm. On the body chamber there are up to six secondaries per primary rib. The secondary ribs have the same direction as the primaries on the phragmocone. On the body chamber the secondary ribs bend forward and form a proconvex arc on the siphonal side. The last whorl covers the preceding one by 55%.

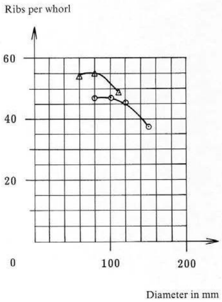


Fig. 66. Rib curves of *Lithacosphinctes pseudolictor* (Choffat).
Circles: MNHB J 26517;
triangles: lectotype in Choffat (1893, pl. 18:7).

Affinities: As Choffat's name suggests, *Lithacosphinctes pseudolictor* resembles *Ammonites lictor* Fontannes in Dumortier & Fontannes (1876). The difference between the two taxa is slight. The dimensions of the holotype as figured by Fontannes in Dumortier & Fontannes (1876, pl. 12:1) are the same as those of MNHB J 26517, and the rib curve of Fontannes' type is also very similar. The main difference between the two specimens is the number of secondary ribs per primary which is four at the diameter of 132 mm in MNHB J 26517 and eight at the same diameter in the holotype of *Ammonites lictor* Fontannes. F. Atrops noted in his review of the study presented here that *Ammonites lictor* Fontannes is a *Progeronia* of the Divisum or of the Acanthicum Chron, whereas *Lithacosphinctes pseudolictor* (Choffat) is of the Platynota Chron. *Lithacoceras (Lithacoceras) pseudolictor* (Choffat) in Geyer (1961, pl. 10:1) has a wider umbilicus than the lectotype in Choffat (1893) and has more secondary ribs per primary at the corresponding growth stage than MNHB J 26517. The primary ribs of Geyer's specimen are nowhere proconcave. *Lithacoceras (Lithacoceras) pseudolictor* (Choffat) in Koerner (1963, pl. 23:2) is much older than the lectotype in Choffat (1893).

Material: 1 specimen: MNHB J 26517.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/Whorl Dm	n
MNHB J 26517	133	146	51	-	62	35	-	43	146 120 100 80	38 46 47 47

Table 28. Dimensions of *Lithacosphinctes pseudolictor* (Choffat).

Genus *Orthosphinctes* Schindewolf, 1925

Subgenus *Orthosphinctes* Schindewolf, 1925

Type species: Ammonites tiziani Oppel, 1863 [m].

Orthosphinctes (Orthosphinctes) uresheimensis (Wegele, 1929) [m]

Fig. 67–68; table 29

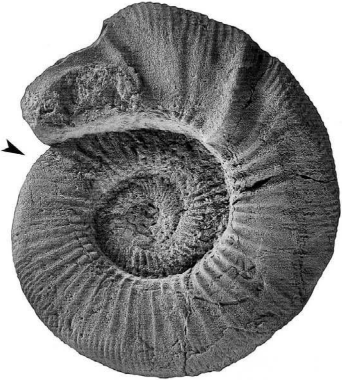
1929b *Perisphinctes uresheimensis* n.sp. – Wegele, p. 54, pl. 3:1.

Holotype: Plate 3:1 in Wegele (1929b).

Type locality: Wallfahrt near Wemding, Franconia, southern Germany.

Type horizon: Platynota Zone.

Description: The carbonate internal mould of MNHB J 23085 is septate to the diameter of 70 mm. The phragmocone is flattened. Four fifths of the last whorl are occupied by the body chamber. Parts of the peristome and of a long lappet are pre-



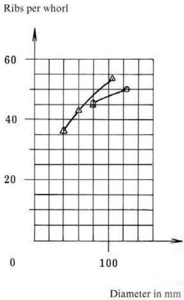


Fig. 68. Rib curves of *Orthosphinctes (Orthosphinctes) uresheimensis* (Wegele). Circles: MNHB J 23085; triangles: holotype.

Fig. 67. *Orthosphinctes (Orthosphinctes) uresheimensis* (Wegele), MNHB J 23085. Section RG 21, quarry on Mt. Born, Olten, Canton Solothurn, bed no. 54: Reuchenette Formation. Coll. R. & S. Gygi. ×1.

served. The primary ribs of the body chamber begin at the umbilical suture line. They swing back on the umbilical margin and become straight and radial on the whorl sides. The ribs have sharp edges. They split at about 60% of the whorl height into three fine secondary ribs. The secondaries on the rear part of the body chamber bend forward, whereas on the last part of the body chamber they have the same direction as the primary ribs. There is a broad constriction on the last part of the body chamber that is followed by a collar. A last, deep constriction is before the peristome.

Affinities: The dimensions of MNHB J 23085 compare well with those of the holotype at the corresponding growth stage. The specimen from Olten has the same sharp-edged primary ribs as the holotype and the same number of secondary ribs per primary. The secondary ribs of the holotype bend forward on the rear part of the body chamber and have the same direction as the primaries near the end of the last whorl like in the specimen J 23085 from Olten. But it can be seen in figure 67 that the inner whorls of specimen J 23085 are more densely ribbed than those of the holotype.

Material: 1 specimen: MNHB J 23085.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 23085	70	117	37	20	49	31	17	42	124 80	50 46

Table 29. Dimensions of *Orthosphinctes (Orthosphinctes) uresheimensis* (Wegele).

Family Ataxioceratidae Buckman, 1921

Subfamily Ataxioceratinae Buckman, 1921

Genus *Ataxioceras* Fontannes, 1879

Subgenus *Ataxioceras* Fontannes, 1879

Type species: Perisphinctes (Ataxioceras) hypselocyclum Fontannes, 1879 [M].

Fig. 69. *Ataxioceras (Ataxioceras) arcanum* Schneid, MNHB J 25921.
Section RG 21 (= RG 240), quarry on Mt. Born, Olten, Canton Solothurn, not from *in situ*, collected from rubble blasted out of the lower Reuchenette Formation, beds no. 49–67 (see Gygi, 1969, pl. 18).
Coll. R. & S. Gygi. ×1.

Ataxioceras (Ataxioceras) arcanum Schneid, 1944 [M]
Fig. 69; table 30

1944 *Ataxioceras arcanum* n.sp. – Schneid, p. 34, pl. 12:5–6.

Lectotype: Plate 12:5 in Schneid (1944).

Type locality: Staffelberg near Langheim, Franconia, southern Germany.

Type horizon: Weisser Jura γ 2 or γ 3.

Description: The carbonate internal mould of MNHB J 25921 is septate to the diameter of 126 mm. Three fourths of the last whorl are occupied by the body chamber. This seems to be complete because of a constriction at its end. The whorl section is oval. The primary ribs of the innermost whorls are fine, densely-spaced and are inclined forward. On the last whorl of the phragmocone they become proconcave. The secondary ribs vanish before the siphonal side of the last whorl becomes to be visible. The primary ribs vanish at the end of the phragmocone. Only low, indistinct nodes are traces of them that persist on the umbilical margin of the body chamber. The last whorl covers the preceding one by about a third.

Affinities: The dimensions of MNHB J 25921 are similar to those of the specimen as figured by Schneid (1944, pl. 12:6) that is, according to Schneid (1944:35), septate to the diameter of about 140 mm. But the specimen from Olten has a wider umbilicus, and its last whorl covers the preceding one only by about a third as compared with about 60% in the specimen in Schneid (1944, pl. 12:6). The ribbing of J 25921 compares well with that of the specimen in Schneid (1944, pl. 12:6). *Ataxioceras (Ataxioceras) suberinum* (von Ammon) is, according to the photograph of a cast of the holotype in Geyer (1961, pl. 13:1), of lesser size than that of the taxon by Schneid.

Material: 1 specimen: MNHB J 25921.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 25921	126	204	66	39	85	32	19	42	115	26

Table 30. Dimensions of *Ataxioceras (Ataxioceras) arcanum* Schneid.

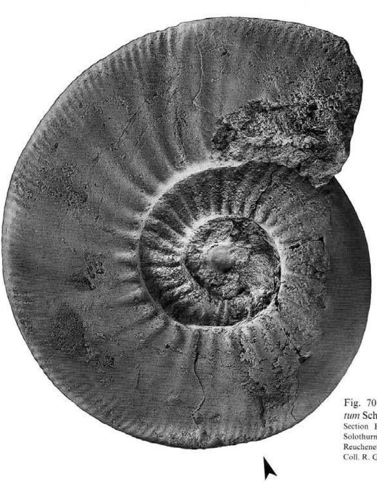


Fig. 70. *Ataxioceras (Ataxioceras) complanatum* Schneid, MNHB J 32817.
Section RG 28, Halden east of Schönenwerd, Canton Solothurn, base of bed no. 47 (section unpublished): lower Reuchenette Formation.
Coll. R. Gygi. ×1.

Ataxioceras (Ataxioceras) complanatum Schneid, 1944 [M]
Fig. 70–71; table 31

1944 *Ataxioceras complanatum* n.sp. – Schneid, p. 20, pl. 6:1–2.
? 1961 *Ataxioceras (Ataxioceras) complanatum* Schneid – Geyer, p. 59, text-fig. 76–77, pl. 13:3.

Holotype: Plate 6:1 in Schneid (1944).

Type locality: Zeegendorf, Franconia, southern Germany.

Type horizon: Weisser Jura γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 32817 is septate to the diameter of 105 mm. Two thirds of the last whorl are occupied by the body chamber. The whorl section is high-oval. The primary ribs of the inner whorls begin at the umbilical suture line. They swing back on the umbilical margin. On the whorl sides they are straight and have a strong forward inclination. On the body chamber, the primary ribs begin on the umbilical margin. The primaries split on the inner whorls (visible on the reverse of the photographed side) high on the whorl sides. On the body chamber, the point of division becomes diffuse and is much lower down on the whorl sides. There are four secondary ribs per primary on the body chamber. The secondaries have a stronger forward inclination than the primary ribs and form a proconvex arc on the siphonal side. The ribbing is subdued on the last preserved part of the body chamber. The last whorl covers the preceding one by about 50%.

Affinities: The holotype, to judge of Schneid's photograph and text, is septate to the diameter of about 120 mm and, if this be correct, is somewhat larger than MNHB J 32817. The innermost visible primary ribs of the holotype are relatively widely spaced and strong like in J 32817. The rib curve of MNHB J 32817 (fig. 71) is therefore almost flat, not inclined

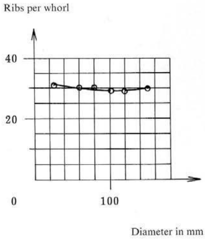


Fig. 71. Rib curve of *Ataxioceras (Ataxioceras) complanatum* Schneid, MNHB J 32817.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32817	105	148	53	34	54	36	23	36	148 120 100 80 60 25	30 29 29 30 30 31

Table 31. Dimensions of *Ataxioceras (Ataxioceras) complanatum* Schneid.

as is represented on text-figure 76 in Geyer (1961). The primary ribs on the body chamber of J 32817 are a little stronger than those on the holotype at the corresponding growth stage, and they are not swollen into nodes on the umbilical margin.

Material: 1 specimen: MNHB J 32817.

Genus *Pachyplanulites* Spath, 1930

Type species: Perisphinctes subevolutus Waagen, 1875, designated here.

Remark: The genus *Pachyplanulites* Spath is so far only known from the indo-madagascan faunal province. Representatives of the genus of Early Kimmeridgian age were figured by Spath (1930) and by Venzo (1942 and 1959).

Pachyplanulites? n.sp. [M]
Fig. 72–74; table 32

1888 *Ammonites divisus coronatus* – Quenstedt, p. 961, pl. 106:6.

Description: The glauconitic, carbonate internal mould of MNHB J 32631 is septate to the diameter of 248 mm. Half of the last whorl is occupied by the body chamber. The body chamber is deformed and incomplete. The whorl section at the end of the phragmocone is depressed (fig. 74). The primary ribs are strong and sharp on the inner whorls. At the beginning of the last whorl of the phragmocone, the primary ribs suddenly become higher and more distant. They have a forward inclination of 5–10°. The point of division of the primary ribs is very high on the sides of the inner whorls and is at the siphonal margin on the last whorl of the phragmocone. The primary ribs split into bundles of three secondaries. Intercalated between the bundles are one or two loose secondary ribs, so that there are four to five secondary ribs per primary. The secondary ribs are weak and blunt near the end of the phragmocone and probably vanish on the body chamber. The siphonal side of the last whorl of the phragmocone is only slightly convex. The whorls cover each other very little.

Affinities: Ammonites similar to MNHB J 32631 were assigned to the genus *Katroliceras* Spath by Geyer (1961). According to Verma & Westermann (1984), *Katroliceras* appear in Kenya only in the Late Kimmeridgian, Beckeri Zone (cited from a letter of 26/1/2001 by G. Schweigert). J 32631 then cannot be assigned to *Katroliceras*. Hantzpergue (1989:157,

Fig. 72. *Pachyplanulites*? n.sp., MNHB J 32631.
Lower quarry south of Löchli south of Schönenwerd, Canton Solothurn: Reuchenette Formation.
×0.7.

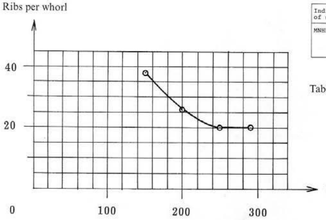


Fig. 73. Rib curve of *Pachyplanulites*? n.sp., MNHB J 32631.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32631	248	273	56	-	151	21	-	55	290 250 200 150	20 20 26 38

Table 32. Dimensions of *Pachyplanulites*? n.sp.

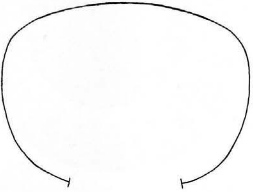


Fig. 74. Whorl section of *Pachyplanulites*? n.sp., MNHB J 32631.
At the diameter of 220 mm.

pl. 12b) published *Tolvericeras (Tolvericeras) murogense* Hantzpergue that has some similarity with J 32631, but this taxon is of the Autissiodorensis Chron of the Late Kimmeridgian. The earliest *Tolvericeras,* according to Hantzpergue (1989:152), are from the Mutabilis Chron. The only forms similar to J 32631 known from the Early Kimmeridgian are *Ammonites divisus coronatus* Quenstedt from Weisser Jura γ and *Pachyplanulites* n.sp. aff. *subevolutus* (Waagen) as figured by Venzo (1942, pl. 1:1–2). Venzo assigned this ammonite from near Harer in eastern Ethiopia to the Tenuilobatus Zone. This might be conspecific with *Ammonites divisus coronatus* in Quenstedt (1888, pl. 106:6). Therefore, J 32631 (fig. 72) is assigned tentatively to the genus *Pachyplanulites* Spath. This solution is unsatisfactory, because the type species of *Pachyplanulites* as designated here is, according to Waagen (1875), from the Dhosa oolite. Arkell in Arkell et al. (1957:321) regarded *Pachyplanulites* as a synonym of *Kranaosphinctes* of the Middle Oxfordian. Spath (1930:44) thought that *Pachyplanulites* was of Early Kimmeridgian age. Possibly the best solution would be to introduce a new generic name for forms like J 32631 from the Early Kimmeridgian of Central Europe, when more material will be available.

Katroliceras garnieri (Fontannes) in Andelkovic (1966, pl. 12:1) may be conspecific with *Pachyplanulites*? n.sp. MNHB J 32631. *Perisphinctes acer* Neumayr (1873, pl. 38:1b) has an oval whorl section. Moreover, the ribbing of the specimen figured by Neumayr (1873) on plate 37 is much looser on the inner whorls than in MNHB J 32631, and the point of division into secondary ribs is at the umbilical margin.

Material: 1 specimen: MNHB J 32631.

Fig. 75. *Pachypictonia bornensis* n.sp., MNHB J 26519, holotype, not from *in situ*.
Collected from rubble (= RG 240) blasted out of the succession of beds no. 49–67 of section RG 21, quarry on Mt. Born, Olten, Canton Solothurn: Reuchenette Formation.
Coll. R. & S. Gygi.

×0.6.

Family Aulacostephanidae Spath, 1924

Subfamily Pictoniinae Spath, 1924

Genus *Pachypictonia* Schneid, 1940

Type species: Pictonia indicatoria Schneid, 1940.

Pachypictonia bornensis n.sp. [M]
Fig. 75–76; table 33

Holotype: MNHB J 26519, figure 75.

Type locality: Section RG 21, quarry on Mt. Born, Olten, Canton Solothurn.

Type horizon: Not from *in situ*, collected from rubble (= RG 240) blasted out of the lower Reuchenette Formation (beds no. 49–67 of section RG 21, see Gygi, 1969a, pl. 18). To conclude of the matrix of the internal mould, the holotype is from bed no. 59 of section RG 21.

Derivation of the name: The name refers to Mt. Born near Olten, Canton Solothurn, where the holotype was found.

Diagnosis: Very large form of the genus *Pachypictonia* with a phragmocone of a diameter of around 280 mm. The taxon grows to a diameter estimated at 400 mm. The section of the last whorl is thick-oval. No ribs are visible from a diameter of ca. 80 mm, but the whorl sides of the body chamber form low, distant waves.

Description: The carbonate internal mould of the holotype is septate to the diameter of 278 mm. Half of the last whorl is occupied by the body chamber. The section of the last whorl is thick-oval (fig. 76). The rounded umbilical wall of the last whorl is steep and touches the preceding whorl at an angle of almost 90°. There are two indistinct umbilical ribs at the diameter of ca. 80 mm. Then the whorl sides become smooth. On the whorl sides of the body chamber, there are three distant, low waves instead of ribs. The last whorl covers the preceding one by 52%.

Affinities: The lectotype of the similar *Pictonia* (*Pachypictonia, Divisosphinctes*?) *divergens* Schneid (1940, pl. 12(8):1), designated here, has primary ribs to the diameter of ca. 150 mm. The absence of ribs in the holotype of *Pachypictonia bornensis* n.sp. from a diameter of ca. 80 mm suggests that the specimen might belong to the genus *Balticeras*. The only known species of *Balticeras* has a narrower umbilicus at the corresponding growth stage (see MNHB J 26466, fig. 155). There are no waves on the whorl sides of all of the known representatives of *Balticeras*, but comparable waves exist on the whorl sides of *Pachypictonia divergens* Schneid J 24196 (fig. 140) at the corresponding growth stage. Such waves were also found on the whorl sides of *Pachypictonia divergens* (Schneid) J 32811 near the end of the phragmocone (fig. 142). But the umbilicus of the inner whorls of that specimen is narrower than in *Pachypictonia bornensis* n.sp. The closest relative to *Pachypictonia bornensis* n.sp. is *Pachypictonia divergens* (Schneid) that is ribbed to a greater diameter than *Pachypictonia bornensis* n.sp.

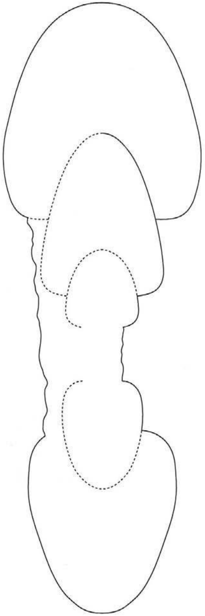


Fig. 76. Cross-section of *Pachypictonia bornensis* n.sp., holotype, MNHB J 26519. ×0.6.

Material: 1 specimen: MNHB J 26519.

Differential diagnosis: Pachypictonia bornensis n.sp. differs from the similar *Pachypictonia divergens* (Schneid) in that its last primary ribs are visible at the diameter of 80 mm as compared with 150 mm in *Pachypictonia divergens. Balticeras pommerania* Dohm has a narrower umbilicus at the growth stage corresponding to the holotype of *Pachypictonia bornensis,* and it has no waves on the whorl sides of late growth stages.

Fig. 77. *Eurasenia gemina* (Schneid), MNHB J 26520, not from *in situ*.
Collected from rubble (= RG 240) blasted out of the succession of beds no. 49–67 of section RG 21, quarry on Mt. Born, Olten, Canton Solothurn:
Reuchenette Formation.
Coll. R. & S. Gygi. ×0.7.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26519	278	352	127	106	123	36	30	35		

Table 33. Dimensions of *Pachypictonia bornensis* n.sp.

Subfamily Aulacostephaninae Spath, 1924

Genus *Eurasenia* Geyer, 1961

Type species: Ammonites rolandi Oppel, 1863.

Eurasenia gemina (Schneid, 1939)
Fig. 77

1939 *Rasenia gemina* n.sp. – Schneid, p. 128, pl. 5(1):1.

Holotype: Kreisnaturaliensammlung Bayreuth, plate 5(1):1 in Schneid (1939).

Type locality: Muggendorf, Franconia, southern Germany.

Type horizon: Malm γ.

Description: MNHB J 26520 is only a fragment that cannot be measured exactly. It was collected from rubble (= RG 240) blasted out of beds no. 49–67 of section RG 21 (see Gygi, 1969, pl. 18) at Olten, Canton Solothurn. The specimen is septate to the diameter of ca. 330 mm. The diameter of the complete shell must have been of the order of 480 mm. A small part of the body chamber is preserved. The section of the last whorl is thick-oval. The primary ribs of the inner whorls are very coarse and distant. On the last preserved whorl fragment they are weak and hardly perceptible. There, the point of division into secondary ribs is diffuse. The secondary ribs are weak and blunt and fade away completely at the siphonal side.

Affinities: The holotype in Schneid (1939, pl. 5(1):1) is a fragment like MNHB J 26520. It is smaller than the Swiss specimen and wholly septate (Schneid, 1939:129). The (completed) number of primary ribs per half whorl and the number of secondary ribs per primary of J 26520 correspond well to what can be seen on the photograph of the holotype. The inner whorls of J 26520 are depressed and are similar to *Eurasenia balteata* (Schneid) (fig. 145).

Material: 1 specimen: MNHB J 26520.

Genus *Involuticeras* Salfeld, 1913

Type species: Ammonites involutus Quenstedt, 1849.

Involuticeras involutum (Quenstedt, 1846)
Fig. 78–79; table 34

1961 *Rasenia (Involuticeras) involuta* (Quenstedt) – Geyer, p. 102, text-fig. 124a, text-fig. 126i, text-fig. 130–132, pl. 3:7, pl. 9:8, with synonymy.

Holotype: University of Tübingen, Museum für Geologie und Paläontologie, without number, plate 12:9 in Quenstedt (1846–1849).

Type locality: Region of Heuberg near Nusplingen, southern Germany.

Type horizon: Middle Weisser Jura.

Fig. 78. *Involuticeras involutum* (Quenstedt), MNHB J 4578.
Quarry of Rothenhof near Schönenwerd, Canton Solothurn: Reuchenette Formation.
Coll. J. Hürzeler. ×1.

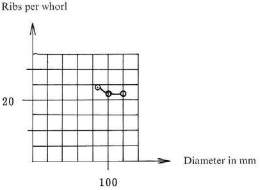


Fig. 79. Rib curve of *Involuticeras involutum* (Quenstedt), MNHB J 4578.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 4578	118	110	46	36	31	42	33	28	120 100 87	21 21 24

Table 34. Dimensions of *Involuticeras involutum* (Quenstedt).

Description: The glauconitic, carbonate internal mould of MNHB J 4578 is septate to the diameter of 118 mm. The beginning of the body chamber is preserved. The umbilical suture line of the last half whorl shows a distinct egression. The specimen is then probably adult even though the last two septa are not approximated. The whorl section is oval. The primary ribs of the inner whorls begin at the umbilical suture line. On the last whorl the vertical umbilical wall is smooth, and the primary ribs begin only at the umbilical margin where they swing back. Then they become radial. Most of them fade away completely in the middle of the whorl sides. The secondary ribs are straight and radial. They are very fine and crowded on the innermost visible whorl. They are not attenuated at the siphonal side. There are mostly four secondary ribs per primary. The last whorl covers the preceding one by 47%.

Affinities: The holotype has a diameter of only 72 mm and is wholly septate. There its umbilicus has a width of 14 mm as compared with 16 mm in MNHB J 4578 at the same growth stage. The Swiss specimen is three quarters of a whorl larger than the wholly septate holotype. It has 21 primary ribs on the last whorl like the holotype. Both specimens have four secondary ribs per primary. The umbilicus on the last whorl of J 4578 is with 0.28 considerably wider than that of the holotype (0.19) because of the egression of the last half whorl.

Material: 1 specimen: MNHB J 4578.

Fig. 80. *Balticeras pommerania* Dohm, MNHB J 32816.
Section RG 21, quarry on Mt. Born, Olten, Canton Solothurn, bed no. 59: Reuchenette Formation.
Coll. R. Gygi. ×0.4

Genus *Balticeras* Dohm, 1925

Type species: Balticeras pommerania Dohm, 1925.

Balticeras pommerania Dohm, 1925 [M]
Fig. 80–81

v* 1925 *Balticeras Pommerania* n.sp. – Dohm, p. 34, pl. 5:1–3.
v 1957 *Balticeras pommerania* Dohm – Arkell in Arkell et al., p. L 324, fig. 416/1a–b.

Holotype: University of Greifswald, Geologische Landessammlung, without number, plate 5:2 in Dohm (1925).

Type locality: Quarry near Czarnoglowy (= former German Zarnglaff), Poland.

Type horizon: Upper Jurassic.

Description: The carbonate internal mould of MNHB J 32816 is septate to the diameter of ca. 390 mm. The exact figure cannot be established, because the siphonal side at the end of the phragmocone is broken off. The body chamber occupies two fifths of the last whorl. The (completed) section at the end of the last whorl is thick-oval (fig. 81). The umbilical suture line shows a marked egression from the beginning of the last whorl. The egression is 1.8 at the umbilical width of 136 mm. The specimen is then probably adult although the last septa are not approximated. The whorls are smooth from an umbilical width of about one centimeter. The lower umbilical wall of the inner whorls is almost vertical.

Affinities: The holotype was measured to have a diameter of 198 mm. It is a wholly septate nucleus. Its whorls are smooth from an umbilical width of about one centimeter like in MNHB J 32816. The fine accretion lines that are visible on one of the whorl sides of J 32816 at the diameter of about 200 mm are not preserved on the holotype.

Material: 1 specimen: MNHB J 32816.

3.2.2 Perisphinctaceans of the Baden Member

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Lithacosphinctes* Olóriz, 1978

Lithacosphinctes sp.gr. *pseudolictor* (Choffat, 1893) [M]
Fig. 82–83; table 35

Synonymy: see

1893 *Perisphinctes pseudolictor*, Choffat, sp.nov. – Choffat, p. 48, pl. 18:7–9.

Description: The glauconitic, carbonate internal mould of MNHB J 26443 is wholly septate. The section of the last whorl is oval. The primary ribs of the inner whorls are distinct,

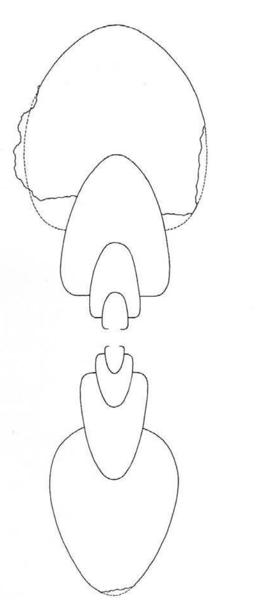


Fig. 81. Cross-section of *Balticeras pommerania* Dohm MNHB J 32816. ×0.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whor	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26443	Nu	216	66	-	99	30	-	46	220 200 160 120 80	30 35 45 50 41

Table 35. Dimensions of *Lithacosphinctes* sp. gr. *pseudolicto* (Choffat).

Fig. 82. *Lithacosphinctes* sp.gr. *pseudolictor* (Choffat), MNHB J 26443.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×0.9.

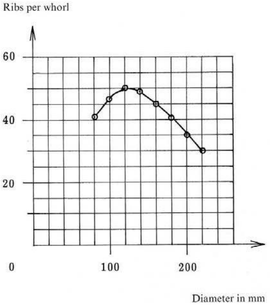


Fig. 83. Rib curve of *Lithacosphinctes* sp.gr. *pseudolictor* (Choffat), MNHB J 26443.

straight and radial. They are attenuated from the diameter of 100 mm. Only faint, swollen nodes remain of the primary ribs on the umbilical margin of the last whorl. The secondary ribs are weak and fade away completely at the diameter of 190 mm. They have a stronger forward inclination than the primaries. There are six secondary ribs per primary on the last whorl. From the diameter of 190 mm on, the siphonal side is smooth. Three deep constrictions are visible on the four preserved whorls.

Affinities: MNHB J 26443 is larger than *Perisphinctes pseudolictor* in Choffat (1893, pl. 18:7). It has a wider umbilicus at the corresponding growth stage than the Portuguese taxon. The rib curve of Choffat's taxon culminates at the diameter of 80 mm (fig. 66 of this study) as compared with 120 mm in J 26443 (fig. 83). *Ammonites lictor evolutus* in Quenstedt (1887/88, pl. 105:2) is more evolute than J 26443. It is also smaller: Its last septum was observed by the author to be at the diameter of only 167 mm. The primary ribs of Quenstedt's taxon do not fade away in the course of ontogeny. F. Atrops in his review of this study drew attention to the similarity of the form described here with *Lithacoceras (Lithacoceras) evolutum* (Quenstedt) in Schairer (1974:77).

Material: 1 specimen: MNHB J 26443.

Genus *Orthosphinctes* Schindewolf, 1925

Subgenus *Orthosphinctes* Schindewolf, 1925

Orthosphinctes (Orthosphinctes) freybergi (Geyer, 1961) [m]
Fig. 84–85; table 36

1982 *Orthosphinctes (Orthosphinctes) freybergi* (Geyer) – Atrops, p. 59, table 2, text-fig. 10, pl. 15:1–2; pl. 19:4, with synonymy.

Holotype: Plate 8:1 in Geyer (1961).

Type locality: Staffelberg near Staffelstein, Franconia, southern Germany.

Type horizon: Lower Weisser Jura γ.

Description: The glauconitic, carbonate internal mould of MNHB J 26335 is septate to the diameter of 89 mm. Half of the last whorl is occupied by the body chamber. The whorl section is high-oval. The fine and crowded primary ribs swing back on the umbilical margin. They are straight on the whorl sides where they lean 8–10° forward. The primary ribs split at 70% of the whorl height into two secondary ribs that have a greater forward inclination than the primaries. The secondary

Fig. 84. *Orthosphinctes (Orthosphinctes) freybergi* (Geyer), MNHB J 26335.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

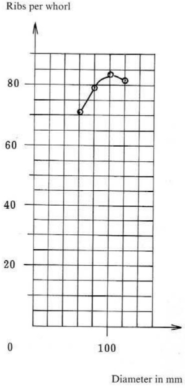


Fig. 85. Rib curve of *Orthosphinctes (Orthosphinctes) freybergi* (Geyer), MNHB J 26335.

ribs form a proconvex arc on the siphonal side and are not attenuated along the siphonal line. The last whorl covers the preceding one by 31%. One narrow and shallow constriction is hardly perceptible on the body chamber.

Affinities: MNHB J 26335 is probably conspecific with *Orthosphinctes (Orthosphinctes) freybergi* (Geyer, 1961). But its umbilicus is narrower than that of the holotype as well as that of the specimens listed by Atrops (1982, table 2). J 26335 has much more primary ribs per whorl than the holotype at the diameter of 100 mm. The secondary ribs of the specimen from Mellikon bend more forward than those of the holotype.

Material: 1 specimen: MNHB J 26335.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26335	89	117	39	-	46	33	-	39	120 100 80 60	81 84 79 71

Table 36. Dimensions of *Orthosphinctes (Orthosphinctes) freybergi* (Geyer).

Orthosphinctes (Orthosphinctes) postcolubrinus (Wegele, 1929) [m]
Fig. 86–87; table 37

1929b *Perisphinctes postcolubrinus* n.sp. – Wegele, p. 55, pl. 3(7):3.

Holotype: Plate 3 (7): 3 in Wegele (1929).

Type locality: Wallfahrt near Wemding, Franconia, southern Germany.

Type horizon: Platynota Zone.

Description: The best-preserved of the figured specimens, MNHB J 24188 (fig. 86c), is septate to the diameter of 35 mm. Almost the entire last whorl is occupied by the body chamber that is complete to the constriction before the peristome. The section of the body chamber is thick-elliptical and compressed. The next inner whorl is slightly depressed. The primary ribs begin at the umbilical suture line. They are radial, high and sharp-edged on the body chamber. The last two primary ribs are approximated. The primaries split at 75% of the whorl height into two or three secondary ribs that have the same direction as the primaries. The last whorl covers the preceding one only slightly. This specimen has 46 primary ribs on the last whorl (fig. 87). The ribbing of the other two figured specimens is looser.

Affinities: The size of the holotype by Wegele (1929b) is more than twice that of MNHB J 24188. The holotype is septate to the diameter of ca. 78 mm, and the diameter of the complete shell must have been around 120 mm. J 24188 has more primary ribs per whorl than the holotype, and its ribs are mostly dichotome. J 26300 (fig. 86a) is closer to the holotype: it is septate to the diameter of 63 mm, and the primary ribs of it are predominantly tripartite. However, it has a narrower umbilicus than the holotype. J 24188 and J 26299 (not figured) have both a deep and narrow constriction. Constrictions are not visible on the photograph of the holotype, but they are said to be narrow and shallow in the text by Wegele (1929b:55).

Material: 4 specimens: MNHB J 24188, J 24313, J 26299, J 26300.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26300	63	85	27	22	41	32	26	48	85 60	38 33
MNHB J 24313	62	75	22	20	37	29	26	50	85 60	40 38
MNHB J 24188	35	63	18	17	30	29	27	48	63 40	46 39
MNHB J 26299	?	63	20	21	30	32	33	48	63	37

Table 37. Dimensions of *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele).

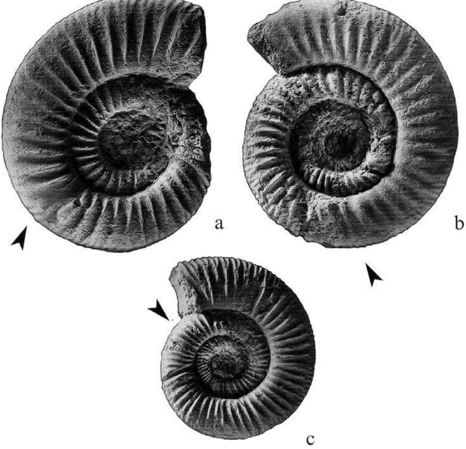


Fig. 86. *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele).
a: MNHB J 26300;
b: MNHB J 24313;
c: MNHB J 24188.
All specimens from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

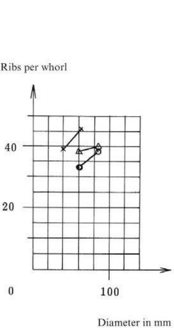


Fig. 87. Rib curves of *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele).
Circles: MNHB J 26300;
triangles: MNHB J 24313;
crosses: MNHB J 24188.

a

b

Fig. 88. *Orthosphinctes (Orthosphinctes) pseudopolyplocoides* (Geyer).
a: MNHB J 26316, coll. R. & S. Gygi;
b: MNHB J 32822, coll. E. Romano.
Both from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124; lower Baden Member.
×1.

Orthosphinctes (Orthosphinctes) pseudopolyplocoides (Geyer, 1961) [m]

Fig. 88–89; table 38

1961 *Lithacoceras (Progeronia) pseudopolyplocoides* n.sp. – Geyer, p. 33, table 13, pl. 8:2–3, pl. 10:3.

non 1992 *Orthosphinctes (Orthosphinctes)* cf. *pseudopolyplocoides* (Geyer) – Finkel, p. 235, fig. 3.

Holotype: Plate 8:3 in Geyer (1961).

Type locality: Aalen, southern Germany.

Type horizon: Boundary between Weisser Jura β and γ.

Description: The glauconitic, carbonate internal mould of MNHB J 26316 is septate to the diameter of 92 mm. Four fifths of the last whorl are occupied by the body chamber. This is complete, because the last two ribs are approximated and have a greater forward inclination than the preceding ones. The peristome is not preserved. The section of the last whorl is oval. The primary ribs of the inner whorls begin at the umbilical suture line. On the last whorl they begin on the umbilical margin above a smooth umbilical wall. The primary ribs are proconcave on the whorl sides and have a forward inclination of 6–10°. They are low and blunt on the last whorl. At 75% of the whorl height they split into two to five weak secondary ribs. The secondaries form a proconvex arc on the siphonal side of the body chamber. No secondary ribs are visible at the end of the phragmocone where the siphonal side is smooth.

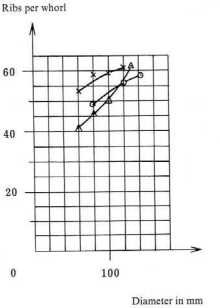


Fig. 89. Rib curves of *Orthosphinctes (Orthosphinctes) pseudopolyplocoides* (Geyer).
Circles: MNHB J 26316;
triangles: MNHB J 32822;
crosses: MNHB J 24193.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
NMHB J 32822	107	120	37	32	53	31	27	45	130	62
									100	51
									80	46
									60	41
MNHB J 24193	106	96	30	24	43	31	25	44	120	61
									100	59
									80	58
									60	53
									40	47
MNHB J 26316	92	142	41	30	70	29	21	49	145	58
									120	56
									100	50
									80	48

Table 38. Dimensions of *Orthosphinctes (Orthosphinctes) pseudopolyplocoides* (Geyer).

There are two deep constrictions on the body chamber. The last whorl covers the preceding one by ca. 20%.

Affinities: The dimensions and the ribbing of MNHB J 26316 correspond well to the holotype of *Orthosphinctes (Orthosphinctes) pseudopolyplocoides* (Geyer). *Perisphinctes pseudobreviceps* Wegele (1929b, pl. 3(7):2) of the Platynota Chron is closely related, but it has less secondary ribs per primary rib at the end of the body chamber. Enay (1966:527) drew attention to the fact that Wegele's specific name is preoccupied by *Perisphinctes pseudo-breviceps* n.f. Simionescu (1907:54, text-fig. 32, pl. 8:1). Consequently, Geyer's new taxon *Orthosphinctes (Orthosphinctes) pseudopolyplocoides* is justified.

Material: 2 specimens: MNHB J 26316, J 32822.

Subgenus *Ardescia* Atrops, 1982

Subgeneric type species: Ataxioceras desmoides Wegele, 1929.

Orthosphinctes (Ardescia) desmoides quenstedti Atrops (1982) [m]

Fig. 90–91; table 39

1982 *Orthosphinctes (Ardescia) desmoides quenstedti* nov.subsp. – Atrops, p. 71, table 4, text-fig. 12, pl. 5:1, 5; pl. 6:11; pl. 28:4, with synonymy.

Holotype: Plate 5:1 in Atrops (1982).

Type locality: Montagne de Crussol, St-Péray, Département Ardèche, France.

Type horizon: Platynota Zone, Desmoides Subzone.

Description: The glauconitic, carbonate internal mould of MNHB J 26314 is septate to the diameter of 94 mm. Half of the last whorl is occupied by the body chamber. The section of the last whorl is oval. The primary ribs of the inner whorls begin at the umbilical suture line. On the last whorl they begin in the upper part of the umbilical wall. They are straight from the beginning. Their forward inclination is 2–10°. They split at 66% of the whorl height into two or three secondary ribs. The secondary ribs have the same direction as the primaries at the beginning of the last whorl, but they bend forward at the end of the phragmocone and on the body chamber and then form

Fig. 90. *Orthosphinctes (Ardescia) desmoides quenstedti* Atrops, MNHB J 26314.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

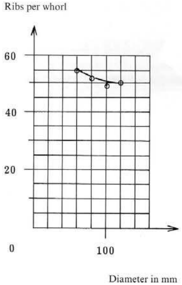


Fig. 91. Rib curve of *Orthosphinctes (Ardescia) desmoides quenstedti* Atrops, J 26314.

a proconvex arc on the siphonal side. There is a deep, narrow constriction on the last whorl.

Affinities: The rib curve of MNHB J 26314 is slightly descending (fig. 91). This is characteristic for the subspecies *desmoides quenstedti* (see Atrops, 1982, text-fig. 12). But the phragmocone of J 26314 is larger than that of the representatives of the subspecies as listed by Atrops (1982, table 4). Moreover, J 26314 has more primary ribs per whorl and less secondary ribs per primary than the specimens as figured by Atrops (1982).

Material: 1 specimen: MNHB J 26314.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26314	94	95	29	21	47	30	22	49	120 100 80 60	50 49 48 52

Table 39. Dimensions of *Orthosphinctes (Orthosphinctes) desmoides quenstedti* Atrops.

Orthosphinctes (Ardescia) inconditus (Fontannes in Dumortier & Fontannes, 1876) [m]

Fig. 92–93; table 40

1982 *Orthosphinctes* (m. *Ardescia*) *inconditus* (Fontannes) – Atrops, p. 104, table 11, text-fig. 19, pl. 1:2–4, pl. 3:8, pl. 10:8–9, pl. 20:4, 6, pl. 29:2–3, with synonymy.
non 1992 *Orthosphinctes (Ardescia) inconditus* (Fontannes) – Finkel, p. 235, fig. 5, with synonymy.

Lectotype: Plate 10:8 in Fontannes (1879).

Type locality: Château de Crussol near Valence, France.

Type horizon: Assises inférieures et moyennes du château.

Description: The glauconitic, carbonate internal mould of MNHB J 24357 is septate to the diameter of 55 mm. Three fourths of the last whorl are occupied by the body chamber. This is complete, because a last constriction and an upwarping before the peristome are visible at the end of the body cham-

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24357	55	78	22	17	40	28	21	50	80 60 40 20	41 36 31 34
MNHB J 24217	50	68	19	17	33	29	25	49	71 40 17	36 35 32

Table 40. Dimensions of *Orthosphinctes (Ardescia) inconditus* (Fontannes).

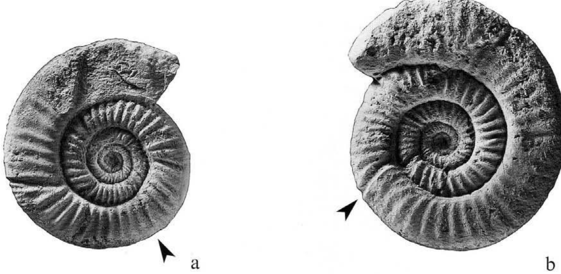


Fig. 92. *Orthosphinctes (Ardescia) inconditus* (Fontannes).
a: MNHB J 24217;
b: MNHB J 24357.
Both specimens from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124; Lower Baden Member. Coll. R. & S. Gygi. ×1.

ber on the reverse of the photographed side. The section of the last whorl is trapezoidal with almost flat, slightly converging whorl sides and a rounded siphonal side. The primary ribs of the inner whorls begin at the umbilical suture line. They are straight and radial or have a forward inclination of at most 8°. On the body chamber, the primaries begin at the umbilical margin above a smooth umbilical wall. Most of the primary ribs split at a whorl height of ca. 70% into two to three weak secondary ribs that have the same direction as the primaries. There are two constrictions on the last whorl.

Affinities: MNHB J 24357 has a larger phragmocone than the lectotype (see Atrops, 1982, table 11). J 24357 has a maximum of three secondary ribs per primary rib as compared with a maximum of four in the lectotype. A photograph of a plaster cast of the lectotype is figured by Geyer (1961, pl. 16:2). The rib curves of this taxon are variable and have little diagnostic value (compare fig. 93 of this study with fig. 19 in Atrops, 1982).

Material: 2 specimens: MNHB J 24217, J 24357.

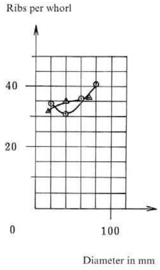


Fig. 93. Rib curves of *Orthosphinctes (Ardescia) inconditus* (Fontannes).
Circles: MNHB J 24357;
triangles: MNHB J 24217.

Genus *Progeronia* Arkell, 1953

Subgenus *Hugueninsphinctes* Atrops, 1982

Subgeneric type species: Ammonites breviceps Quenstedt, 1887/88.

Progeronia (Hugueninsphinctes) sp.

Fig. 94–95; table 41

Description: The glauconitic, carbonate internal mould of MNHB J 26333 is septate to the diameter of 62 mm. Two thirds of the last whorl are occupied by the body chamber. The specimen was somewhat compressed during diagenesis perpendicularly to the coiling axis and can therefore be measured only approximately. The section of the last whorl is high-trapezoidal with almost flat sides that converge towards the siphonal side. The siphonal side is rounded. The fine, sharp primary ribs of the last whorl begin at the umbilical margin and there swing back. The umbilical wall of the last whorl is smooth. The primary ribs are straight on the whorl sides of the phragmocone and of the rear part of the body chamber. There they lean 7–10° forward. The primary ribs become pro-concave on the last quarter whorl of the body chamber. They split at a variable whorl height into two secondary ribs. There are one or two intercalated secondary ribs per primary, so that there is a total of three to four secondary ribs per primary. The secondary ribs bend a little more forward than the primaries and form a proconvex arc on the siphonal side. No constrictions are visible. The last whorl covers the preceding one by about 50%.

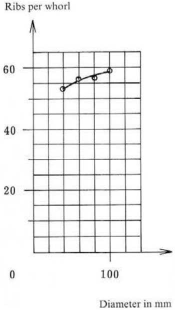


Fig. 95. Rib curve of *Progeronia (Hugueninsphinctes)* sp., MNHB J 26333.

Fig. 94. *Progeronia (Hugueninsphinctes)* sp., MNHB J 26333. Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Affinities: The dimensions and the ornamentation of MNHB J 26333 have some similarity with the holotype of *Progeronia progeron* (von Ammon). A plaster cast of this holotype is figured in Geyer (1961, pl. 7:2). According to an oral communication by Atrops, the holotype of *Progeronia progeron* is wholly septate and is probably a macroconch. J 26333 seems to be rather a microconch and is therefore assigned to the subgenus *Hugueninsphinctes* that was proposed by Atrops (1982:63).

There is some similarity between *Progeronia (Hugueninsphinctes)* sp. J 26333 and the holotype of *Discosphinctes arussiorum* Dacqué. The cast J 30535 of this holotype is depicted in figure 96. The dimensions of *Discosphinctes arussiorum* Dacqué, as far as they can be established on the cast, are close

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26333	62	104	40	29	34	39	28	32	104 80 60 40	58 57 57 53

Table 41. Dimensions of *Progeronia (Hugueninsphinctes)* sp.

Fig. 96. *Discosphinctes arussiorum* Dacqué, cast MNHB J 30535 of the holotype in the Bayerische Staatssammlung, München, Germany.
According to Dacqué (1904:122), the holotype was found in the yellow-brown limestone of the Kimmeridgian near Atchabo, Somalia, together with *Aspidoceras altenense* (d'Orbigny).
Cast by courtesy of A. Zeiss, Erlangen. ×1.

to those of *Progeronia (Hugueninsphinctes)* sp. J 26333 at the corresponding growth stage. The last whorl of *Discosphinctes arussiorum* Dacqué is somewhat crushed diagenetically in the coiling plane. The whorls of *Progeronia (Hugueninsphinctes)* sp. are thicker. *Discosphinctes arussiorum* seems to be septate to the diameter of ca. 75 mm, and it is probably almost complete. It is a little larger than *Progeronia (Hugueninsphinctes)* sp. J 26333. There is a maximum of three secondary ribs per primary in *Discosphinctes arussiorum* as compared with four in the Swiss specimen. There are two unsplit primary ribs on the last whorl of *Discosphinctes arussiorum.* Some of the primary ribs split in a polygyrate pattern in both taxa, and the primary ribs split at a varying whorl height in both *Discosphinctes arussiorum* and *Progeronia (Hugueninsphinctes)* sp. The secondary ribs of both taxa form a proconvex arc at the siphonal side.

Progeronia (Hugueninsphinctes) sp. J 26333 has a narrower umbilicus than *Perisphinctes Roubyanus* Fontannes (1879, pl 8:6) that is the type species of the genus *Discosphinctoides* as proposed by Olóriz (1978:481). The Swiss specimen J 26333 has almost the same dimensions as *Perisphinctes ardescicus* Fontannes (1879, pl. 8:3), if the drawing in Fontannes (1879) is correct. The taxon by Fontannes is the type species of the subgenus *Pseudodiscosphinctes* by Olóriz (1978:490). The ribbing of *Progeronia (Hugueninsphinctes)* sp. J 26333 resembles that of *Perisphinctes ardescicus* Fontannes in the irregular whorl height at which the primary ribs split. But *Perisphinctes ardescicus* Fontannes has more crowded primary ribs, and there are as a rule only two secondary ribs per primary in Fontannes' taxon.

Material: 1 specimen: MNHB J 26333.

Family Simoceratidae Spath, 1924

Subfamily Idoceratinae Spath, 1924

Genus *Idoceras* Burckhardt, 1906

Type species: Ammonites balderus Oppel, 1863, designated here.

Idoceras hararinum Venzo, 1942
Fig. 97

1942 *Idoceras hararinum* Venzo – Venzo, p. 48, pl. 6:8, pl. 7:2–4, pl. 12:3.
1959 *Idoceras hararinum* Venzo – Venzo, p. 151, pl. 6:8, pl. 7:2–4, pl. 12:3.

Lectotype: Plate 7:3b in Venzo (1959), designated here.

Type locality: Malcà Balcad Gebiss near Harer, eastern Ethiopia.

Type horizon: Tenuilobatus Zone.

Description: The glauconitic, carbonate internal mould of MNHB J 24356 is probably wholly septate. The section of the last whorl is high-oval. The whorl sides are only sligtly convex. The inner whorls are very evolute. The umbilicus has a width of 28.5 mm at the diameter of 52 mm or 55% of the diameter. The primary ribs of the inner whorls are strong and radial. They are not attenuated at the whorl sides. The majority of them splits at about 50% of the whorl height into two secondary ribs that bend forward. There are unsplit primary ribs at the diameter of 52 mm. Only part of the strong secondary ribs is interrupted at the siphonal side at this diameter. On the last whorl, the primary ribs fade away almost completely on the whorl sides. On the last half whorl the secondary ribs are all interrupted along a narrow, smooth siphonal band. There are three secondary ribs per primary at this ontogenetic stage. There, at the diameter of 118 mm, the whorl height is much greater than in the inner whorls and reaches 39% of the diameter, whereas the umbilicus is reduced to 41% of the diameter. The last whorl covers the preceding one by more than 50%.

Affinities: The specimen MNHB J 24356 as represented in figure 97 is much larger than *Ammonites Balderus* as figured by Oppel (1863, pl. 67:2). The original to Oppel's figure 2 in plate 67 is here designated as lectotype. This is, according to Oppel (1863, caption to pl. 67:2), a nucleus. The final size of *Idoceras hararinum* J 24356 is estimated to be at least 200 mm. Specimens of that size were already mentioned and assigned to *Idoceras balderum* by Ziegler (1959:26). The inner whorls of J 24356 are much more evolute than those of the lectotype of *Idoceras balderum* at the corresponding growth stage. The secondary ribs of J 24356 are not flattened as is considered to be

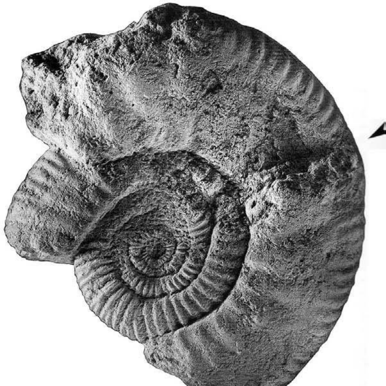


Fig. 97. *Idoceras hararinum* Venzo, MNHB J 24356.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

characteristic for the taxon *balderum* by Ziegler (1959:26). It is inappropriate to assign large and evolute forms like J 24356 to the taxon *balderum* (Oppel), because J 24356 is older than typical *Idoceras balderum* from the lowermost Wettingen Member (see below). On the other hand, J 24356 is very similar to *Idoceras hararinum* Venzo (1959, pl. 7:3b) that is now the lectotype. J 24356 is probably not conspecific with *Idoceras balderum largiombelicatum* Sarti (1993:114, text-fig. 57, pl. 24:1–2) that has a wider umbilicus at the diameter of 100 mm and is of smaller size. The subspecific name by Sarti (1993) must be corrected to *largumbilicatum* according to the rules mentioned below.

Material: 1 specimen: MNHB J 24356.

Genus *Nebrodites* Burckhardt, 1912

Subgenus *Nebrodites* Burckhardt, 1912

Subgeneric type species: Simoceras agrigentinum Gemmellaro, 1872.

Nebrodites (Nebrodites) aff. *passendorferiformis* Caracuel et al. (1999)
Fig. 98

aff. 1999 *Nebrodites passendorferiiforme* n.sp. – Caracuel et al., p.114, table 2, fig. 5–14.

Emendation: The original spelling of the specific name by Caracuel et al. is *passendorferiiforme.* According to the International Code of Zoological Nomenclature (1964), Article 32, this must be corrected to *passendorferiformis.* The name refers to Edward Passendorfer, a Polish palaeontologist.

Holotype: Figures 5–9 in Caracuel et al. (1999).

Type locality: Sierra de Lugar, Province of Murcia, Spain.

Type horizon: Upper Platynota Zone.

Fig. 98. *Nebrodites (Nebrodites)* aff. *passendorferiformis* Caracuel et al., emend. Gygi, MNHB J 32833.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. Gygi. ×1.

Description: MNHB J 32833 depicted in figure 98 is a complete adult with the last constriction before the peristome and part of a lappet on the left (figured) side. The diameter of the shell is 30 mm, the whorl height 7.5 mm (25%), the whorl thickness 6.2 mm (21%) and the width of the umbilicus 17 mm (57%). The section of the last whorl is thick-oval. Simple and radial primary ribs alternate regularly with dichotome ribs on the body chamber. The siphonal side is smooth and rounded.

Affinities: MNHB J 32833 is very similar to *Nebrodites (Nebrodites) macerrimus* (Quenstedt) in Ziegler (1959, pl. 1:18) from Weisser Jura γ (Kimmeridgian) of Nendingen, southern Germany. Quenstedt (1887 in 1887/88, caption to pl. 94:44) stated that his taxon was from Weisser Jura α (Oxfordian) of Lochengründle, a locality near Balingen, southern Germany. Ziegler (1959:41) thought that the horizon of *macerrimus* as indicated by Quenstedt was erroneous. However, Schweigert & Callomon (1997:35) reported a new find of *"Nebrodites macerrimus* (Quenstedt) [m] from the *bimammatum* horizon of southern Germany that confirms the statement by Quenstedt (1887). Consequently, Kimmeridgian forms like no. 19553 in the Staatliches Museum für Naturkunde, Stuttgart, as figured by Ziegler (1959), and MNHB J 32833 as figured in this paper (fig. 98) need another name. Caracuel et al. (1999:114, fig. 5–9) published a similar form from the Kimmeridgian upper Platynota Zone of southern Spain. J 32833 differs from *Nebrodites passendorferiformis* Caracuel et al. in that it does not have depressed inner whorls, and that there are no constrictions in the inner whorls. J 32833 is probably not conspecific with *Nebrodites passendorferiformis* Caracuel et al.

Material: 1 specimen: MNHB J 32833.

Subgenus *Mesosimoceras* Spath, 1925

Subgeneric type species: Simoceras cavouri Gemmellaro, 187

Nebrodites (Mesosimoceras) risgoviensis (Schneid, 1915)
Fig. 99

1915 *Simoceras Risgoviensis* n.sp. – Schneid, p. 95, pl. 2:5.
1978 *Nebrodites (Mesosimoceras) risgoviensis* (Schneid) – Oló p. 180, pl. 15:3–4.
non 1988 *Nebrodites (Mesosimoceras) risgoviensis* (Schneid) – Fezer Geyer, p. 219, pl. 7:3.

Holotype: Plate 2:5 in Schneid, 1915.

Type locality: Wemding, Franconia, southern Germany.

Type horizon: Boundary beds between Polyplocus and Pseu mutabilis Zone.

Description: The glauconitic, carbonate internal mould MNHB J 26508 is septate to the diameter of 105 mm. Only beginning of the body chamber is preserved. The diamete the complete shell is estimated at 140 mm. The section of last whorl is rectangular. The whorl sides and the siphonal are only slightly convex. The shell could be measured at the ameter of 105 mm. There, the whorl height is 25.4 mm (24

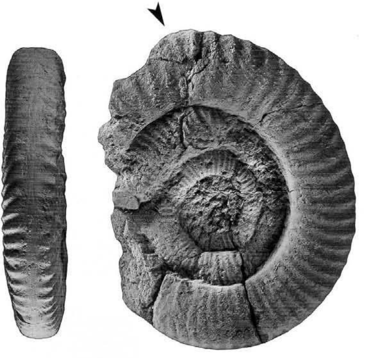


Fig. 99. *Nebrodites (Mesosimoceras) risgoviensis* (Schneid), MNHB J 26508.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

the whorl thickness 20 mm (19%) and the width of the umbilicus 57 mm (55%). The umbilical wall of the last whorl is smooth, and the primary ribs begin there only on the umbilical margin. The primary ribs are proconcave on the last whorl, but straight and radial on the inner whorls. All of the preserved primary ribs of the last whorl are simple. Some dichotome primary ribs are visible on the inner whorls. The primary ribs are weakest near the umbilical margin and strongest at the siphonal margin. There they end abruptly. The siphonal side is flat and smooth.

Affinities: MNHB J 26508 is smaller than the holotype as figured by Schneid (1915) that has a diameter of about 180 mm. The ribbing of 26508 compares very well with that of the holotype except in the dichotome ribs of J 26508. No dichotome ribs are visible on the inner whorls of Schneid's photograph of the holotype. Schneid (1915:95) stated that the siphonal side of the holotype was flat, but he drew the siphonal side to be concave in the whorl section given in plate 2:5. The umbilicus of the specimen as figured by Olóriz (1978, pl. 15:4) is wider than that of the holotype and of MNHB J 26508, and its ribs are more crowded. *Praesimoceras herbichi* (von Hauer) in Neumayr (1873, pl. 40:1) has much less primary ribs on the last whorl and has a rounded siphonal side.

Material: 1 specimen: MNHB J 26508.

Genus *Praesimoceras* Sarti, 1990

Type species: Praesimoceras nodulatum (Quenstedt, 1888).

Emendation: The original spelling of the genus is *Presimoceras* by Sarti (1990:44). According to the International Code of Zoological Nomenclature (1964), Article 32, this must be corrected. The correct spelling is *Praesimoceras.*

Praesimoceras cf. *herbichi* (von Hauer, 1866)
Fig. 100

cf. 1990 *Presimoceras herbichi* (von Hauer) – Sarti, fig. 10.

Description: The glauconitic, carbonate internal mould of MNHB J 26509 is septate to the diameter of 32 mm. One third of the last whorl is occupied by the body chamber. The diameter of the complete shell is estimated at 50 mm. The specimen is somewhat compressed diagenetically in a plane parallel to the coiling axis. The dimensions can therefore be measured only approximately at the diameter of 38 mm in a plane which is parallel to the coiling axis, but inclined 45° with respect to the plane of maximum compression. The whorl height is 9 mm (24%), the whorl thickness also 9 mm (24%), and the width of the umbilicus is 21 mm (55%). The whorl section is nearly quadrate with only slightly convex whorl sides and a flattened to somewhat rounded siphonal side. The primary ribs are sharp and begin at the umbilical suture line. They are straight and radial. There are about 40 primary ribs on the last whorl. Most of the primary ribs of the last whorl are simple, but three dichotome ribs can be discerned. There is a narrow, smooth band along the siphonal side. A deep constriction is at the diameter of ca. 33 mm.

Fig. 100. *Praesimoceras* cf. *herbichi* (von Hauer), MNHB J 26509.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Affinities: Praesimoceras cf. *herbichi* (von Hauer) MNHB J 26509 is larger than *Nebrodites (Mesosimoceras) hossingensis* (Fischer) and has blunt primary ribs that are occasionally dichotome. Moreover, there is a deep constriction. Constrictions do not occur in Fischer's form which has acute and unsplit primary ribs. J 26509 is therefore rather an inner whorl or a juvenile of *Praesimoceras herbichi* (von Hauer) as was presumed by G. Schweigert in a letter dated 26/1/2001.

Material: 1 specimen: MNHB J 26509.

Family Ataxioceratidae Buckman, 1921

Subfamily Ataxioceratinae Buckman, 1921

Genus *Ataxioceras* Fontannes, 1879

Subgenus *Ataxioceras* Fontannes, 1879 [M]

Subgeneric type species: Perisphinctes (Ataxioceras) hypselocyclus Fontannes (1879), caption to plate 10:1–4.

Ataxioceras (Ataxioceras) scitulum Schneid, 1944 [M]
Fig. 101–102; table 42

1944 *Ataxioceras scitulum* n.sp. – Schneid, p. 8, pl. 1:13.

Holotype: Plate 1:13 in Schneid (1944).

Type locality: Tiefenellern, Franconia, southern Germany.

Type horizon: Weisser Jura γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 26421 is septate to the diameter of 81 mm. One third of the last whorl is occupied by the body chamber. The whorl section is high-oval. The primary ribs begin at the umbilical suture line and swing back on the rounded umbilical wall and margin. They are strongest at the umbilical margin. They are attenuated towards the blurred point of division into secondary ribs. The point of division is below 50% of the whorl height. There are six to seven secondary ribs per primary. The secondary ribs have at the beginning the same direction as the primaries. But on the siphonal side they bend forward and form a proconvex arc. There is a constriction at the diameter of 93 mm. The last whorl covers the preceding one by 77%.

Affinities: The holotype of *Ataxioceras (Ataxioceras) scitulum* Schneid has a diameter of 82 mm, and Schneid (1944:8) thought that it is wholly septate. The holotype has 36 primary ribs on the last whorl, whereas there are only 25 primaries at the diameter of 80 mm in MNHB J 26421. There are up to six

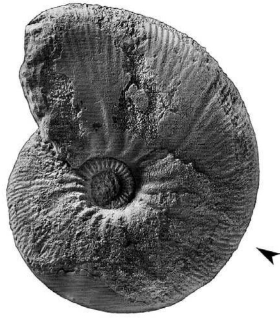


Fig. 101. *Ataxioceras (Ataxioceras) scitulum* Schneid, MNHB J 26421.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26421	81	105	51	28	18	49	27	17	105 80 60	22 25 28

Table 42. Dimensions of *Ataxioceras (Ataxioceras) scitulum* Schneid.

secondary ribs per primary in the holotype as compared with six to seven in J 26421. The umbilicus of J 26421 is with 17% even narrower than that of the holotype of *Ataxioceras (Ataxioceras) scitulum* Schneid which is 22% of the diameter. J 26421 resembles with its narrow umbilicus *Ataxioceras (Ataxioceras) involutum* Geyer (1961, pl. 6:5), which has an umbilicus of 20% of the diameter. Geyer's taxon has even less primary ribs per whorl at the diameter of 77 mm than J 26421 at the corresponding growth stage. But the secondary ribs of *Ataxioceras (Ataxioceras) involutum* Geyer are not as numerous and fine as in J 26421 and in the holotype of *Ataxioceras (Ataxioceras) scitulum* Schneid. *Ataxioceras (Ataxioceras) involutum* Geyer is smaller than *Ataxioceras (Ataxioceras) scitulum* Schneid, because its phragmocone has a diameter of only 57 mm as compared with 81 mm in J 26421. Geyer (1961:61) regarded *Ataxioceras (Ataxioceras) scitulum* Schneid to be a synonym of *Ataxioceras (Ataxioceras) pulchellum* Schneid. But the umbilicus of the holotype of *Ataxioceras (Ataxioceras) pulchellum* Schneid (1944, pl. 11:7) is with 23% somewhat wider than that of *Ataxioceras (Ataxioceras) scitulum* Schneid, and the whorl sides of *Ataxioceras (Ataxioceras) pulchellum* Schneid are flatter than those of *Ataxioceras (Ataxioceras) scitulum* Schneid. The differences between the three discussed taxa are slight, and the question must be asked whether these taxa should be reunited in one under the name *scitulum* Schneid.

Material: 1 specimen: MNHB J 26421.

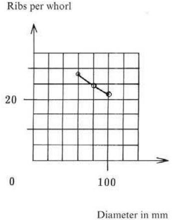


Fig. 102. Rib curve of *Ataxioceras (Ataxioceras) scitulum* Schneid, MNHB J 26421.

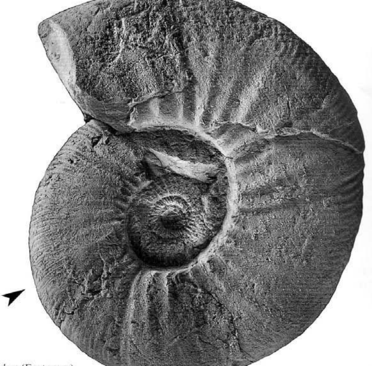


Fig. 103. *Ataxioceras (Ataxioceras) discobolum* (Fontannes), MNHB J 26346.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Ataxioceras (Ataxioceras) discobolum (Fontannes in Dumortier & Fontannes, 1876) [M]

Fig. 103–104; table 43

1961 *Ataxioceras (Ataxioceras) discobolum* (Fontannes) – Geyer, p. 65, text-fig. 86–87, pl. 7:4–5, pl. 13:5, with synonymy.
1992 *Ataxioceras (Ataxioceras) discobolum* (Fontannes) – Finkel, p. 240, fig. 25, fig. 38.

Holotype: Plate 13:1 in Dumortier & Fontannes (1876).

Type locality: Crussol near Valence, France.

Type horizon: Zone à *Ammonites polyplocus.*

Description: The glauconitic, carbonate internal mould of MNHB J 26346 is septate to the diameter of 87 mm. It is slightly deformed diagenetically and could be measured only approximately. Three fourths of the last whorl are occupied by the body chamber. The whorl section is high-oval. The primary ribs of the body chamber begin on the umbilical margin where they swing back. The umbilical wall of the body chamber is smooth. The primary ribs are somewhat proconcave on the whorl sides and have a mean forward inclination of 11–14°. They are attenuated at the indistinct point of division into secondary ribs which is at about half the whorl height.

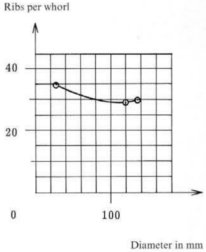


Fig. 104. Rib curve of *Ataxioceras (Ataxioceras) discobolum* (Fontannes), MNHB J 26346.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26346	87	135	48	30	48	34	22	35	135	30
									120	29
									100	32
									30	35

Table 43. Approximate dimensions of *Ataxioceras (Ataxioceras) discobolum* (Fontannes).

The secondary ribs bend forward and form a proconvex arc on the siphonal side. There are four to five secondaries per primary rib. The last whorl covers the preceding one by about 50%.

Affinities: MNHB J 26346 seems to be almost complete although the last three septa are not approximated. The specimen is a little larger than the holotype which is a complete adult. J 26346 has 30 primary ribs on the last whorl as compared with 31 in the holotype. The whorl height of the holotype is 35% of the diameter as compared with 34% in J 26346. The umbilicus of J 26346 (35%) is narrower than that of the holotype (40%), but the ribbing of both specimens is very similar.

Material: 1 specimen: MNHB J 26346.

Ataxioceras (Ataxioceras) arcanum Schneid, 1944 [M]

Fig. 105–107; table 44

1944 *Ataxioceras arcanum* n.sp. – Schneid, p. 34, pl. 12:5–6.

Holotype: Plate 12:5 in Schneid (1944).

Type locality: Staffelberg near Langheim, Franconia, southern Germany.

Type horizon: Weisser Jura γ 2.

Description: The carbonate internal mould of MNHB J 26340 is septate to the diameter of 122 mm. Four fifths of the last whorl are occupied by the body chamber. This is nearly complete, because the last two primary ribs are approximated. The specimen is then adult. This is also indicated by the umbilical wall, the inclination of which diminishes on the last quarter whorl to about 45° at the end of the body chamber. The section of the last whorl is high-oval. The umbilical wall is smooth on the last whorl. The primary ribs begin where the umbilical wall grades into the rounded umbilical margin. The ribs are strongest above the umbilical margin. Most of them fade away completely in the middle of the whorl sides. There are seven to eight fine secondary ribs per primary at the beginning of the last half whorl where the secondary ribs fade away. The secondary ribs form a proconvex arc on the siphonal side. Only low waves remain of the primary ribs on the umbilical margin of the last quarter whorl of the body chamber. The peristome is broken off.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26340	122	184	70	44	57	38	24	31	220	25
									200	25
									160	22
									140	21
									120	23
									100	25
MNHB J 32820	Nu	128	51	31	36	39	24	28	130	23
									100	23?
									60	26?
									40	37?

Table 44. Dimensions of *Ataxioceras (Ataxioceras) arcanum* Schneid.

Fig. 105. *Ataxioceras (Ataxioceras) arcanum* Schneid, MNHB J 26340.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Affinities: The paratype figured by Schneid (1944, pl. 12:6) is septate to the diameter of about 140 mm and is therefore larger than MNHB J 26340. Its whorl section and the ribbing compare very well with MNHB J 26340. J 32820 as represented in figure 106 is a wholly septate nucleus with a broad constriction at the diameter of about 75 mm. Such a constriction can be discerned in the photograph of the holotype at the diameter of 110 mm. *Ataxioceras (Ataxioceras) suberinum* (von Ammon) is a closely related form. A cast of the holotype was figured by Geyer (1961, pl. 13:1) at less than natural size. The diameter of the holotype is about 180 mm according to Geyer (1961, table 41). The primary and the secondary ribs of the holotype of *Ataxioceras (Ataxioceras) suberinum* (von Ammon) fade away or are attenuated earlier than in J 26340 (fig. 105). However, both the primary and the secondary ribs of J 32820 (fig. 1(fade away almost completely at the end of the last whc There are seven secondary ribs per primary at the diameter 80 mm in this specimen, just as Geyer (1961, table 41) indica to be the case in *Ataxioceras (Ataxioceras) suberinum* (v Ammon). According to Geyer (1961, table 41), the dimensic of the holotype of *Ataxioceras (Ataxioceras) suberinum* (v Ammon) are almost exactly the same as those of J 26340 (r resented in table 44, fig. 105) of this study. It is therefore p sible that J 26340 is conspecific with *Ataxioceras (Atax ceras) suberinum* (von Ammon). The problem cannot solved with the material that was available for this study.

Material: 3 specimens: MNHB J 26340, J 26372, J 32820.

Fig. 106. *Ataxioceras (Ataxioceras) arcanum* Schneid, MNHB J 32820.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. Gygi. ×1.

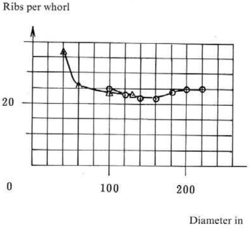


Fig. 107. Rib curves of *Ataxioceras (Ataxioceras) arcanum* Schneid.
Circles: MNHB J 26340;
triangles: MNHB J 32820.

Fig. 108. *Ataxioceras (Ataxioceras)* aff. *illibatum* Schneid, MNHB J 26320.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Ataxioceras (Ataxioceras) aff. *illibatum* Schneid, 1944 [M]
Fig. 108–109; table 45

1944 *Ataxioceras (Perisphinctes?) illibatum* n.sp. – Schneid, p. 24, pl. 7:1–3.

Lectotype: Plate 7:1 in Schneid (1944), designated here.

Type locality: Zeegendorf, Franconia, southern Germany.

Type horizon: Weisser Jura γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 26320 is septate to the diameter of 146 mm. Less than half of the last whorl is occupied by the body chamber. The section of the last whorl is oval. The primary ribs of the phragmocone begin at the umbilical suture line. They swing back on the umbilical wall and at the umbilical margin. They are somewhat proconcave on the whorl sides where they lean 8–12° forward. The primary ribs are strongest on the umbilical wall. On the last half whorl of the phragmocone they fade away completely in the middle of the whorl sides. There are seven fine and weak secondary ribs per primary at the diameter of 125 mm. There are no secondary ribs from the diameter of 127 mm on where the siphonal side becomes smooth after a deep constriction. The last primary rib can be discerned at the diameter of 155 mm. From there on the last whorl is smooth. The last whorl covers the preceding one by 38%. There are three distinct constrictions at the diameters of 115, 125 and 150 mm.

Affinities: The final size of MNHB J 26320 is estimated at about 220 mm. It is then smaller than the lectotype that has a diameter of 245 mm according to Schneid (1944:24). J 26320 has more primary ribs than the lectotype at the diameter of 145 mm (compare fig. 109 in this study with fig. 46 in Atrops, 1982). The primary ribs of J 26320 disappear at the diameter of about 160 mm, whereas they continue to the peristome in

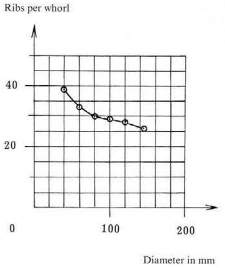


Fig. 109. Rib curve of *Ataxioceras (Ataxioceras)* aff. *illibatum* Schneid, MNHB J 26320.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26320	146	147	46	33	63	31	23	43	145	26
									120	28
									100	29
									80	30
									60	33
									40	38

Table 45. Dimensions of *Ataxioceras (Ataxioceras)* aff. *illibatum* Schneid.

the lectotype. There are no constrictions in the lectotype at the diameters corresponding to the constrictions in J 26320.

Geyer (1961:56) assigned *Ataxioceras (Ataxioceras) illibatum* Schneid to *Ataxioceras (Ataxioceras) eudiscinum* Schneid. This is probably inappropriate, because *Ataxioceras (Ataxioceras) illibatum* Schneid has a considerably wider umbilicus than *Ataxioceras (Ataxioceras) eudiscinum* Schneid. The inner whorls of the latter taxon are more densely ribbed (compare fig. 68 in Geyer, 1961, with fig. 46 in Atops, 1982).

Material: 1 specimen: MNHB J 26320.

Ataxioceras (Ataxioceras) sp. [M]
Fig. 110–111; table 46

Description: The glauconitic, carbonate internal mould of MNHB J 26321 is septate to the diameter of 148 mm. Only about a tenth of the last whorl is occupied by the body chamber. The whorl section is oval. The primary ribs of the phragmocone begin at the umbilical suture line. On the small preserved part of the body chamber, the umbilical wall is smooth, and the primary ribs begin at the umbilical margin. The primary ribs of the inner whorls are straight and have a distinct forward inclination. They fade away in the middle of the whorl sides before they split into secondary ribs. There are four to five fine secondary ribs per primary at the diameter of 110 mm. The secondary ribs have a stronger forward inclination than the primaries and form a proconvex arc on the siphonal side. The primary as well as the secondary ribs persist to the beginning of the body chamber. The last whorl covers the preceding one by about 35%. There is a narrow constriction at the diameter of 90 mm.

Affinities: MNHB J 26321 resembles *Ataxioceras (Ataxioceras)* aff. *illibatum* Schneid J 26320. But the primary ribs of J 26321 are straight and do not swing back on the umbilical margin. They are more crowded on the inner whorls (compare fig. 111 with fig. 109). There is only one, narrow constriction in J 26321 (fig. 110). The rib curve is evidence that J 26321 is an *Ataxioceras,* not a *Lithacosphinctes.*

Material: 1 specimen: MNHB J 26321.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26321	148	143	49	33	58	34	23	41	140	32
									120	38
									100	40
									80	41
									60	42
									40	44

Table 46. Dimensions of *Ataxioceras (Ataxioceras)* sp.

Fig. 110. *Ataxioceras (Ataxioceras)* sp., MNHB J 26321.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

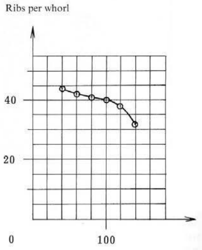


Fig. 111. Rib curve of *Ataxioceras (Ataxioceras)* sp., MNHB J 26321.

Subgenus *Parataxioceras* Schindewolf, 1925 [m]

Subgeneric type species: Ammonites lothari Oppel, 1863.

Ataxioceras (Parataxioceras) pseudolothari Geyer (1961) [m]
Fig. 112–113; table 47

1961 *Ataxioceras (Parataxioceras) pseudolothari* n.sp. – Geyer, p. 68, table 50, text-fig. 96–97, pl. 16:6.

Holotype: Plate 16:6 in Geyer (1961).

Type locality: Zimmern near Pappenheim, Franconia, southern Germany.

Type horizon: Weisser Jura, middle γ.

Description: The glauconitic, carbonate internal mould of MNHB J 24269 is septate to the diameter of 56 mm. Four fifths of the last whorl are occupied by the body chamber that is complete to the last constriction before the peristome. The peristome is not preserved. The whorl section is high-trapezoidal with sides that are very little convex and that converge towards the rounded siphonal side. The primary ribs begin at the umbilical suture line and swing back on the umbilical wall and margin. They are straight on the whorl sides and there lean 8–17° forward. They are strongest on the umbilical margin and are somewhat attenuated at half of the whorl height. The point of division into secondary ribs is at about 50% of the whorl height and even lower near the end of the body chamber. The mode of division is polygyrate to polyplocal (after Schindewolf, 1925, in Geyer, 1961, fig. 6). After the last division, the secondary ribs bend forward with respect to the primaries and form a proconvex arc on the siphonal side. There are six to seven secondary ribs per primary on the body chamber. Five constrictions can be counted on the last whorl.

Affinities: MNHB J 24269 differs from *Ataxioceras (Parataxioceras) lothari* (Oppel) by the more irregular ribbing pattern that resembles to some extent *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele.

Material: 1 specimen: MNHB J 24269.

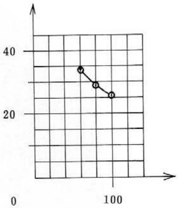


Fig. 113. Rib curve of *Ataxioceras (Parataxioceras) pseudolothari* Geyer, MNHB J 24269.

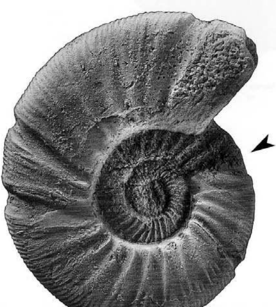


Fig. 112. *Ataxioceras (Parataxioceras) pseudolothari* Geyer, MNHB J 24269.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24269	56	97	37	-	35	38	-	36	100 80 60	26 29 34

Table 47. Dimensions of *Ataxioceras (Parataxioceras) pseudolothari* Geyer.

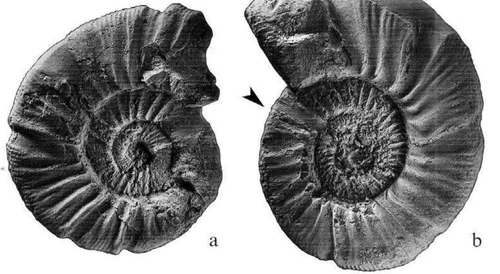


Fig. 114. *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele.
a: MNHB J 26427;
b: MNHB J 24207.
Both section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Ataxioceras (Parataxioceras) pseudoeffrenatum Wegele, 1929 [m]
Fig. 114–115; table 48

1961 *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele – Geyer, p. 69, table 52, text-fig. 100–101, pl. 16:1, with synonymy.
1992 *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele – Finkel, p. 240, fig. 17, fig. 20, non 9.
2000a *Ataxioceras (Parataxioceras)* cf. *pseudoeffrenatum* Wegele – Gygi, p. 96, text-fig. 59, pl. 14:1.

Holotype: Plate 8(12):5 in Wegele (1929b).

Type locality: Kalkofen near Heidenheim i.H., Franconia, southern Germany.

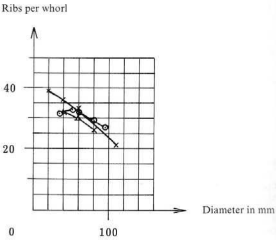
Type horizon: Suberinus Zone.

Description: The glauconitic, carbonate internal mould of MNHB J 24207 is septate to the diameter of 54 mm. Four fifths of the last whorl are occupied by the body chamber. This is complete with the peristome and a lappet on the right side (fig. 114b). The specimen is then adult. A short description and a figure of specimen MNHB J 31721 from the lower Baden Member of Mellikon, Canton Aargau, was given by Gygi (2000a:96 and pl. 14:1).

Fig. 115. Rib curves of *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele.
Circles: MNHB J 24207;
triangles: MNHB J 26427;
crosses: MNHB J 31721.

Affinities: Ataxioceras (Parataxioceras) pseudoeffrenatum Wegele has the most irregular ribbing of all *Parataxioceras*. Gygi (2000a:96) assigned J 31721 with reservation to the taxon, because it has a somewhat wider umbilicus and more primary ribs per whorl than the holotype. This is probably of minor importance, and J 31721 is now regarded to be an *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele.

Material: 3 specimens: MNHB J 24207, J 26427, J 31721.



Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 31721	787	111	37	24	46	33	22	41	111 80 60 40 20	22 26 33 36 39
MNHB J 24207	54	83	29	16	36	35	20	43	95 80 60 35	27 29 32 32
MNHB J 26427	?	87	30	-	36	35	-	41	80 60 40	26 30 32

Table 48. Dimensions of *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele.

Ataxioceras (Parataxioceras) oppeli oppeli Geyer, 1961 [m]

Fig. 116–117; table 49

1961 *Ataxioceras (Parataxioceras) oppeli* n.sp. – Geyer, p. 74, fig. 108–109, pl. 16:4–5.

1982 *Ataxioceras (Parataxioceras) oppeli oppeli* Geyer – Atrops, p. 223, table 35, text-fig. 42, pl. 16:2, 4.

1992 *Ataxioceras (Parataxioceras) oppeli* Geyer – Finkel, p. 239, fig. 10, fig. 45.

Holotype: Plate 16:4 in Geyer (1961).

Type locality: Salmendingen, southern Germany.

Type horizon: Weisser Jura γ.

Description: The glauconitic, carbonate internal mould of MNHB J 26357 is septate to the diameter of 47 mm. Three fourths of the last whorl are occupied by the body chamber. The whorl section is high-oval. The primary ribs begin at the umbilical suture line. They swing slightly back on the umbilical wall and margin. They become straight on the whorl sides. The point of division into three or four secondary ribs is at about 50% of the whorl height on the phragmocone, but it can be very low at the beginning of the body chamber where the ribbing is irregular. The weak secondary ribs have the same direction as the primaries on the phragmocone and on the rear part of the body chamber. They bend forward only near the end of the body chamber and there form a proconvex arc on the siphonal side. There is a deep constriction at the end of the body chamber. The last whorl covers the preceding one by 38%.

Affinities: MNHB J 26357 has about the same size as Geyer's taxon, but its umbilicus is somewhat narrower. J 26357 has very similar dimensions as *Ataxioceras (Parataxioceras) effrenatum* (Fontannes), but it is of greater size.

Material: 2 specimens: MNHB J 26357, J 26379.

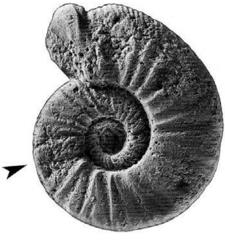


Fig. 116. *Ataxioceras (Parataxioceras) oppeli oppeli* Geyer, MNHB J 26357.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

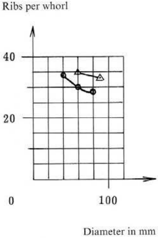


Fig. 117. Rib curves of *Ataxioceras (Parataxioceras) oppeli oppeli* Geyer.
Circles: MNHB J 26357;
triangles: MNHB J 26379.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26379	48	70.8	25.6	16.3	27	32	23	38	90 60	33 35
MNHB J 26357	47	76	28	17	29	37	22	38	80 60 40	28 30 34

Table 49. Dimensions of *Ataxioceras (Parataxioceras) oppeli oppeli* Atrops.

Ataxioceras (Parataxioceras) oppeli hoelderi Geyer, 1961 [m]

Fig. 118–119; table 50

1961 *Ataxioceras (Parataxioceras) hoelderi* n.sp. – Geyer, p. 73, fig. 104–105, pl. 15:3–5.
1982 *Ataxioceras (Parataxioceras) oppeli hoelderi* Geyer – Atrops, p. 229, table 37, fig. 44, pl. 7:1, 5.

Holotype: Plate 15:5 in Geyer (1961).

Type locality: Tieringen, Württemberg, southern Germany.

Type horizon: Weisser Jura γ.

Description: The glauconitic, carbonate internal mould of MNHB J 24270 is septate to the diameter of 58 mm. Three fourths of the last whorl are occupied by the body chamber. The whorl section is oval. The primary ribs begin at the umbilical suture line. They swing slightly back on the umbilical wall and margin. They are straight on the whorl sides where they lean 10–14° forward. The point of division into three to five secondary ribs is at about 50% of the whorl height. The secondary ribs are strong and have the same direction as the primaries on the phragmocone. They bend more forward than the primary ribs only on the body chamber where they form a proconvex arc at the siphonal side. There is a narrow constriction on the body chamber. The last whorl covers the preceding one by 47%.

Affinities: Ataxioceras (Parataxioceras) hoelderi Geyer resembles *Ataxioceras (Parataxioceras) oppeli* Geyer so much that Atrops (1982) regarded the two taxa as subspecies of *oppeli*. Indeed, the dimensions of *Ataxioceras (Parataxioceras) oppeli hoelderi* MNHB J 24270 (fig. 118) are almost the same as those of *Ataxioceras (Parataxioceras) oppeli oppeli* J 26357 (fig. 116). Only the whorl thickness of J 24270 is a little greater than in J 26357 (compare table 49 with 50). *Ataxioceras (Parataxioceras) oppeli hoelderi* J 24270 has a narrower umbilicus than *oppeli oppeli* and somewhat more secondary ribs per primary.

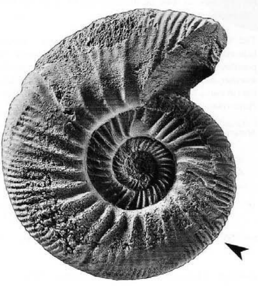


Fig. 118. *Ataxioceras (Parataxioceras) oppeli hoelderi* Geyer, MNHB J 24270.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

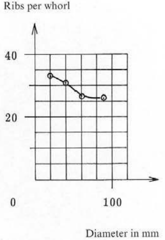


Fig. 119. Rib curve of *Ataxioceras (Parataxioceras) oppeli hoelderi* Geyer, MNHB J 24270.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24270	58	79.5	28.5	20	29.5	36	25	37	90 80 60 40	26 26 27 31

Table 50. Dimensions of *Ataxioceras (Parataxioceras) oppeli hoelderi* Geyer.

Material: 1 specimen: MNHB J 24270.

Ataxioceras (Parataxioceras) homalinum Schneid, 1944 [m]

Fig. 120–121; table 51

1944 *Ataxioceras homalinum* n.sp. – Schneid, p. 13, pl. 5:1–2.
1961 *Ataxioceras (Parataxioceras) effrenatum* (Fontannes) – Geyer, p. 69, pl. 15:1, non 17:3.

Lectotype: Plate 5:1 in Schneid (1944), designated here.

Type locality: Tiefenellern, Franconia, southern Germany.

Type horizon: Malm γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 26334 is septate to the diameter of 78 mm (not indicated by an arrow in fig. 120). Nine eighths, this is to say more than the entire last whorl are occupied by the body chamber. The body chamber ends with a broad and deep constriction and is presumably complete, but the peristome is not pre-

Fig. 120. *Ataxioceras (Parataxioceras) homalinum* Schneid, MNHB J 26334.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

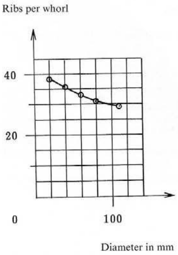


Fig. 121. Rib curve of *Ataxioceras (Parataxioceras) homalinum* Schneid, MNHB J 26334.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26334	78	99	33.4	30.5	40	34	31	40	110 100 80 60 40 20	29 30 32 34 36 38

Table 51. Dimensions of *Ataxioceras (Parataxioceras) homalinum* Schneid.

served. The last two primary ribs are approximated. This is evidence that the specimen is adult. The whorl section is thick-oval. The primary ribs of the inner whorls begin at the umbilical suture line. On the last whorl, some of them begin at the umbilical suture line and others begin somewhat higher up on the umbilical wall. They are straight and radial on the inner whorls, but on the last whorl they swing back on the umbilical wall and margin. The primary ribs of the body chamber are proconcave on the whorl sides and lean a little backward on the last half whorl. They are strong and sharp-edged. The point of division into three to six secondary ribs is at 50–60% of the whorl height. The secondary ribs are quite strong and have the same direction as the primaries. The last whorl covers the preceding one by about 30%.

Affinities: MNHB J 26334 has almost exactly the same size as the lectotype that seems to be complete. The whorl thickness of J 26334 is with 31% considerably greater than that of the lectotype which is 26% according to Schneid (1944:13). But the other dimensions, the mode of ribbing and the number of primary ribs on the last whorl are very similar in both specimens. There are two parabolic nodes on the rear part of the right side (reverse side of fig. 120) of the body chamber of J 26334. No parabolic nodes can be seen on the photograph of the lectotype in spite of the assertion by Schneid (1944:13) that he has seen some.

The whorls of *Ataxioceras (Parataxioceras) homalinum* Schneid are thicker than in any other *Parataxioceras*. This is possibly the reason why Atrops (1982:189) had some doubts whether *homalinum* Schneid was a *Parataxioceras* at all. But the rib curve of J 26334 (fig. 121) is unambiguously that of a *Parataxioceras*.

Material: 1 specimen: MNHB J 26334.

Ataxioceras (Parataxioceras) evolutum Atrops, 1982 [m]

Fig. 122–123, 153; table 52

1982 *Ataxioceras (Parataxioceras) evolutum* nov.sp. – Atrops, p. 215, table 33, text-fig. 40, pl. 4:5, pl. 7:2, pl. 9:5, pl. 43:3, with synonymy.

non 1992 *Ataxioceras (Parataxioceras)* cf. *evolutum* Atrops – Finkel, fig. 13, fig. 31.

Holotype: F.S.L. 226 307, plate 9:5 in Atrops (1982).

Type locality: Butte de Curens près de Monoblet, Département Gard, France.

Type horizon: Lower Lothari Subzone, Hypselocyclum Zone, Kimmeridgian.

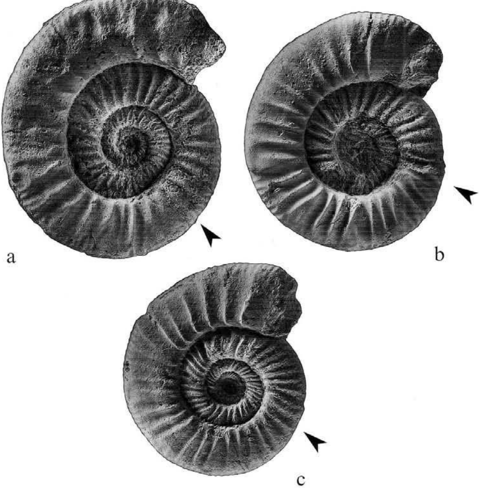


Fig. 122. *Ataxioceras (Parataxioceras) evolutum* Atrops.
a: MNHB J 24310, coll. R. & S. Gygi;
b: MNHB J 26304, don. A. Villa;
c: MNHB J 26397, coll. R. & S. Gygi.
All from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124; lower Baden Member.
×1.

Description: The glauconitic, carbonate internal mould of MNHB J 24310 (fig. 122a) is septate to the diameter of 60 mm. The last two septa are approximated. Three fourths of the last whorl are occupied by the body chamber. The last two primary ribs are attenuated. This and the approximated last septa are evidence that the specimen is a nearly complete adult, but the peristome is not preserved. The whorl section is oval at the end of the phragmocone. It is also oval at the end of the body chamber of J 26304 (fig. 122b). The primary ribs of J 24310 begin at the umbilical suture line. They are strong and blunt. Some of them swing slightly back on the umbilical margin. The primary ribs are straight on the whorl sides where part of them is radial. Some of the primaries lean forward while others lean backward. The mode of division into secondary ribs is variable. There are tripartite and polygyrate ribs on the phragmocone. On the body chamber there are polyplocal ribs. The point of division of polyplocal ribs is low on the whorl sides. There are three to five secondary ribs per primary. The secondary ribs have the same direction as the primaries. The last whorl covers the preceding one very little. There are parabolic nodes on the body chamber of J 26304 (fig. 122b).

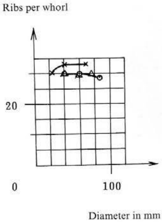


Fig. 123. Rib curves of *Ataxioceras (Parataxioceras) evolutum* Atrops.
Circles: MNHB J 24310;
triangles: MNHB J 26304;
crosses: MNHB J 26397.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24310	60	78.5	22.9	-	37.7	29	-	48	87 60 40	29 30 30
MNHB J 32834	59	83	23	-	41	28	-	49		
MNHB J 26304	49	62.4	18.6	-	28.3	30	-	45	77 60 40	30 29 30
MNHB J 26397	46	67.1	20	16.3	31	30	24	46	70 40 25	33 33 30

Table 52. Dimensions of *Ataxioceras (Parataxioceras) evolutum* Atrops.

Affinities: Ataxioceras (Parataxioceras) evolutum Atrops closely resembles *Orthosphinctes (Ardescia) inconditus* (Fontannes) that is about coeval. The rib curve of *inconditus* MNHB J 24357 rises between the diameters of 40 and 80 mm (fig. 93, circles) whereas it is about horizontal in *evolutum* J 24310 and J 26304 (fig. 123). But the curves can be very similar: compare *inconditus* J 24217 (fig. 93, triangles) with *evolutum* J 26397 (fig. 123, crosses). The main difference between *Ataxioceras (Parataxioceras) evolutum* Atrops and *Orthosphinctes (Ardescia) inconditus* (Fontannes) are the polygyrate and polyplocal ribs as well as the parabolic nodes in *evolutum* that do not occur in *inconditus*.

Material: 4 specimens: MNHB J 24310, J 26304, J 26397, all fig. 122, and J 32834, fig. 153.

Ataxioceras (Parataxioceras) n.sp. [m]

Fig. 124; table 53

Description: The glauconitic, carbonate internal mould of MNHB J 32819 is septate to the diameter of 105 mm. Seven eighths of the last whorl are occupied by the body chamber. The section of the last whorl is oval. The umbilical wall and margin are well-rounded. The primary ribs begin at the umbilical suture line. They are straight from the beginning and almost radial on the preserved part of an inner whorl. From the constriction at the end of the phragmocone on, the primary ribs swing back on the umbilical wall and margin. The primary ribs of the body chamber are straight on the whorl sides, but they have a growing forward inclination towards the end of the body chamber. They split indistinctly polyplocally, then polygyrately into weak secondary ribs at about 50% of the whorl height. There are up to six secondary ribs per primary. The secondary ribs bend a little more forward than the primary ribs and form a proconvex arc on the siphonal side.

Affinities: The indistinctly polyplocal and polygyrate ribs, the deep constrictions affecting the siphonal line and the irregular ribbing of the last third of the body chamber are evidence that MNHB J 32819 is an *Ataxioceras*. The very strong forward inclination of the last rib probably means that the rib is the last one and that the specimen is a nearly complete adult. The ribbing on the first half of the body chamber resembles that of *Ataxioceras (Parataxioceras) hippolytense* Atrops. The width of the umbilicus of MNHB J 32819 resembles that of many *Parataxioceras*. But the size of the specimen is so much greater than that of typical *Parataxioceras* that it cannot be assigned to any taxon of the subgenus that has been described so far. On the other hand, J 32819 is not an *Ataxioceras sensu stricto* because of its wide umbilicus. The specimen cannot be compared with other *Ataxioceras* and certainly belongs to a new taxon. But the incomplete preservation of this ammonite makes the specimen unsuitable to be a holotype.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32819	105	175	50	41	84	28	24	48	180	27

Table 53. Dimensions of *Ataxioceras (Parataxioceras)* n.sp.

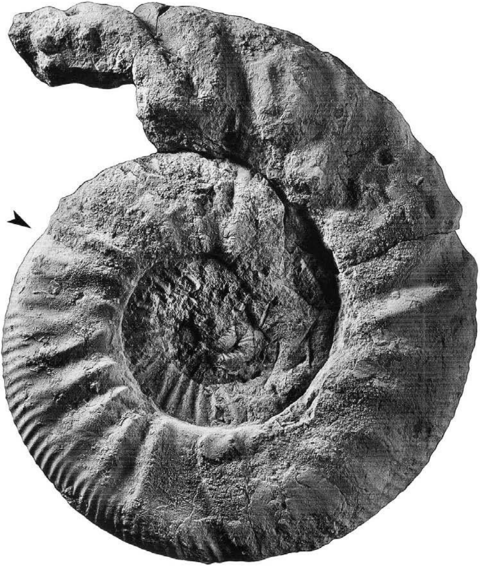


Fig. 124. *Ataxioceras (Parataxioceras)* n.sp., MNHB J 32819.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. Gygi. ×1.

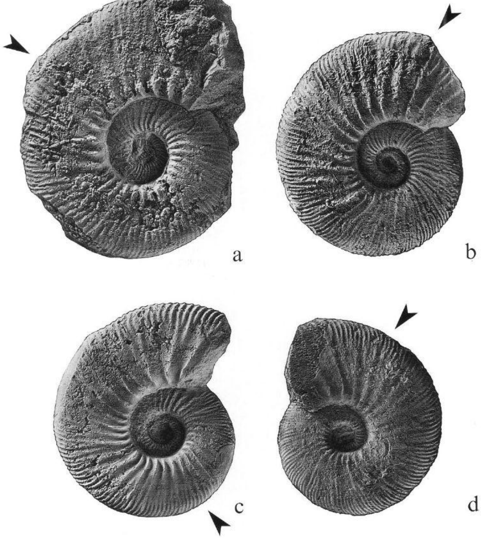


Fig. 125. *Ataxioceras (Schneidia) lussasense* Atrops.
a: MNHB J 32814, coll. R. Gygi;
b: MNHB J 26404, coll. R. & S. Gygi;
c: MNHB J 32818, coll. R. Gygi;
d: MNHB J 24323, coll. R. & S. Gygi.
All specimens from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
×1.

Subgenus *Schneidia* Atrops, 1982

Subgeneric type species: Ataxioceras (Schneidia) collignoni Atrops, 1982.

Ataxioceras (Schneidia) lussasense Atrops, 1982 [m]

Fig. 125–126; table 54

1982 *Ataxioceras (Schneidia) lussasense* nov.sp. – Atrops, p. 177, table 26, text-fig. 33, pl. 2:4, pl. 21:1–6, pl. 22:1–4, pl. 33:3, pl. 34:2, with synonymy.

Holotype: F.S.L. 225 805, plate 22:3 in Atrops (1982).

Type locality: Ravin de Louyre near Lussas, Département Ardèche, France.

Type horizon: Hypselocyclum Zone, Hippolytense Subzone, Kimmeridgian.

Description: The glauconitic, carbonate internal mould of MNHB J 32814 is septate to the diameter of 71 mm. One fourth of the last whorl is occupied by the body chamber. The diameter of the entire shell is estimated at 105 mm. The whorl section is high-trapezoidal and very compressed (table 54). The whorl sides are slightly convex and converge towards the narrow, rounded siphonal side. The primary ribs begin at the umbilical suture line and swing back on the umbilical margin. They are straight on the whorl sides and there lean 12–15° forward. The primary ribs are strongest at the umbilical margin and are attenuated at half of the whorl height. There are up to five secondary ribs per primary. No constrictions are visible in the Swiss material.

The glauconitic, carbonate internal mould of MNHB J 24323 is septate to the diameter of 55 mm. The body chamber occupies only about one fifth of the last whorl. The whorl section is high-oval with slightly convex whorl sides. The umbilical wall and margin are well-rounded. The primary ribs begin at the umbilical suture line and swing back at the umbilical wall and margin. Part of them is straight on the whorl sides and part of them is proconcave. The primary ribs lean 6–17° forward. The ribs are strongest on the umbilical margin and are attenuated in the middle of the whorl sides. The point of division into secondary ribs is mostly blurred. The secondary ribs are strong and bend forward with respect to the primaries. They form a proconvex arc on the siphonal side. There are three to five secondary ribs per primary. The last whorl covers the preceding one by 47%.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32814	71	78	32	17	25	41	22	32	80 60 40	31 33 35
MNHB J 26404	68	65	28	18	18	43	28	28	68 40	34 40
MNHB J 24323	55	58	25.7	14.6	14.2	44	25	24	60 40	26 29
MNHB J 32818	38	67	26	-	22	39	-	33	67 45	30 32

Table 54. Dimensions of *Ataxioceras (Schneidia) lussasense* Atrops.

Affinities: The dimensions of MNHB J 24323 agree well with those of the paratype of *lussasense* F.S.L. 225 847 as figured on plate 21:1 in Atrops (1982). But the ribbing of the specimen figured by Atrops is more crowded. The dimensions and the ribbing of J 24323 are very close to those of the specimen figured on plate 12:6 in Geyer (1961) which seems to be a wholly septate nucleus. Geyer identified that specimen as *Ataxioceras (Ataxioceras) guentheri* (Oppel). According to Atrops (1982:181), the type of *Ammonites Güntheri* Oppel is lost. The quality of figure 1 on plate 66 in Oppel (1863) can therefore not be judged. Atrops (1982:181) was of the opinion that the taxon *guentheri* Oppel should be abondoned. J 24323 is consequently assigned to *Ataxioceras (Schneidia) lussasense* Atrops, because it has only 26 primary ribs on the last whorl, what is at the lower limit of the variability as conceived by Atrops (1982, text-fig. 33).

Ataxioceras (Schneidia) lussasense Atrops differs from *Ataxioceras (Schneidia) genuinum* Schneid in its finer ribbing. *Ataxioceras (Schneidia) genuinum* Schneid and *Ataxioceras (Schneidia) geniculatum* Wegele have deep and broad constrictions affecting the siphonal side. Constrictions affecting the siphonal side occur also in *Ataxioceras (Schneidia) lussasense* (see Atrops, 1982), but they are narrower and not as deep.

Material: 4 specimens: MNHB J 24323, J 26404, J 32814, J 32818.

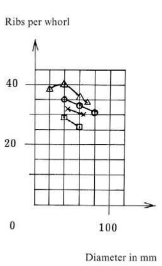


Fig. 126. Rib curves of *Ataxioceras (Schneidia) lussasense* Atrops.
Circles MNHB J 32814;
triangles: MNHB J 26404;
crosses: MNHB J 32818;
squares: MNHB J 24323.

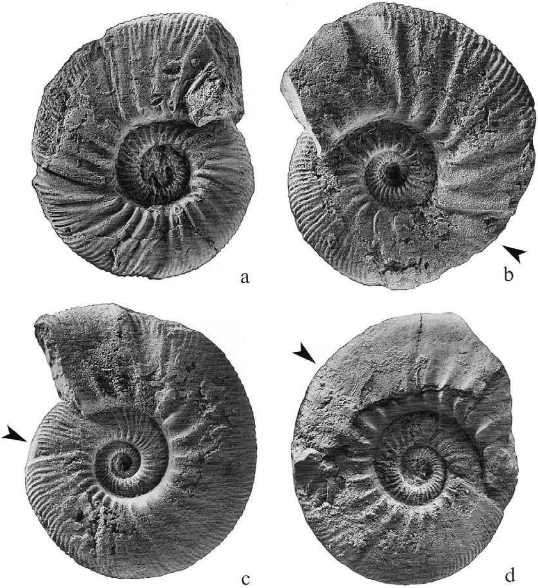


Fig. 127. *Ataxioceras (Schneidia) genuinum* Schneid.
a: MNHB J 4574;
b: MNHB J 26411, coll. R. & S. Gygi;
c: MNHB J 26382, coll. R. & S. Gygi;
d: MNHB J 24265, coll. R. & S. Gygi-
All from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
×1.

Ataxioceras (Schneidia) genuinum Schneid, 1944, [m]

Fig. 127–128; table 55

1944 *Ataxioceras genuinum* n.sp. – Schneid, p. 12, pl. 3:7–9.
cf. 1961 *Ataxioceras (Ataxioceras) genuinum* Schneid – Geyer, p. 58, pl. 13:4.
non 1988 *Ataxioceras (Ataxioceras) genuinum* Schneid – Fezer & Geyer, p. 214, pl. 3:2.

Lectotype: Plate 3:7 in Schneid (1944), designated by Geyer (1961, p. 58).

Type locality: Tiefenellern, Franconia, southern Germany.

Type horizon: Malm γ 2 or γ 3.

Description: The slightly glauconitic, carbonate internal mould of MNHB J 26382 is septate to the diameter of 47 mm. Seven eighths of the last whorl are occupied by the body chamber. The whorl section is high-trapezoidal with almost flat whorl sides and a rounded siphonal side at the end of the phragmocone. The primary ribs begin above the smooth umbilical wall. They swing back on the umbilical margin where they are strongest. They lean 15–25° forward on the lower whorl sides. The primary ribs have first a sharp edge and then are attenuated at half of the whorl height. Some of them fade away completely in the middle of the whorl sides. The point of division is somewhat below half of the whorl height on the phragmocone and is blurred on the body chamber. The mode of division is polygyrate and polyplocal on the phragmocone. There are four to seven weak secondary ribs per primary. The secondary ribs bend more forward than the primaries and form a proconvex arc on the siphonal side. One constriction is at the end of the phragmocone, and two more are on the body chamber. The last whorl covers the preceding one by 50%.

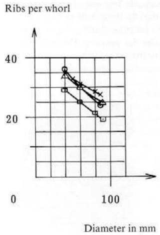


Fig. 128. Rib curves of *Ataxioceras (Schneidia) genuinum* Schneid.
Circles: MNHB J 24265;
triangles: MNHB J 26382;
crosses: MNHB J 4574;
squares: MNHB J 26411.

J 24265 is septate to the diameter of 78 mm. Only one-fourth of the last whorl of this specimen is occupied by the body chamber. The secondary ribs on the body chamber are faint (fig. 127a).

Affinities: According to Schneid (1944, caption to pl. 3), three-fourths of the last whorl of the lectotype are occupied by the body chamber. The lectotype is then septate to the diameter of about 60 mm and is considerably larger than MNHB J 26382 (fig. 127c). The wholly septate syntype figured on plate 3:8 by Schneid (1944) has a diameter of 80 mm (measured on the photograph) and is then even larger than J 24265 (fig. 127d). The dimensions and the ribbing of *Ataxioceras (Schneidia) genuinum* Schneid resemble *Ataxioceras (Schneidia) lussasense* Atrops. The ribbing of *Ataxioceras (Schneidia) genuinum* is stronger than that of *Ataxioceras (Schneidia) lussasense.*

Material: 4 specimens: MNHB J 4574, J 24265, J 26382, J 26411.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24265	78	84.5	30.4	18.4	29.5	36	22	35	87 60 40	24 30 36
MNHB J 26411	51	88.5	36.4	-	26.5	41	-	30	90 80 60 40	19 22 25 29
MNHB J 26382	47	70.7	28.5	-	22.3	40	-	32	90 60 40	25 30 34
MNHB J 4574	45?	77.4	30	17.2	25.5	39	22	33	90 80 60 50	27 28 31 32

Table 55. Dimensions of *Ataxioceras (Schneidia) genuinum* Schneid.

Ataxioceras (Schneidia) geniculatum Wegele, 1929 [m]

Fig. 129; table 56

1929b *Ataxioceras geniculatum* n.sp. – Wegele, p. 71, pl. 7:9.
1974 *Ataxioceras (Parataxioceras) geniculatum* Wegele – Schairer, p. 76, table 24, pl. 9:11.

Holotype: Plate 7:9 in Wegele (1929b).

Type locality: Kirchheim near Pappenheim, Franconia, southern Germany.

Type horizon: Suberinus Zone.

Description: The glauconitic, carbonate internal mould of MNHB J 24322 is septate to the diameter of 32 mm. Almost the entire last whorl is occupied by the body chamber that is apparently complete with a high collar after the last constriction. The peristome is not preserved. The whorl section is high-trapezoidal with a rounded siphonal side at the end of the phragmocone and becomes ellipsoidal on the body chamber. The primary ribs begin at the umbilical suture line. They swing back on the umbilical wall and margin. They are

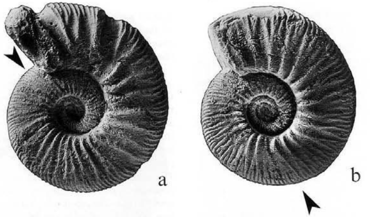


Fig. 129. *Ataxioceras (Schneidia) geniculatum* Wegele.
a: MNHB J 24322;
b: MNHB J 24221.
Both from section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

straight on the whorl sides and there lean 8–18° forward. The point of division into secondary ribs is at 70% of the whorl height at the end of the phragmocone and as low down as 50% of the whorl height on the body chamber. There are two to five secondary ribs per primary. The mode of division is dichotome, polygyrate and polyplocal. The secondary ribs have a stronger forward inclination than the primaries and form a proconvex arc on the siphonal side. Three constrictions can be counted on the body chamber. The last whorl covers the preceding one by 33%.

Affinities: Ataxioceras (Schneidia) geniculatum Wegele resembles *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele to some extent. Geyer (1961:69) included *geniculatum* in the synonymy of *pseudoeffrenatum*. The two taxa are here kept separate, because *geniculatum* is markedly smaller than *pseudoeffrenatum* and has a narrower umbilicus.The ornamentation of *geniculatum* becomes very irregular only towards the end of the body chamber, whereas it is irregular on the whole body chamber of the larger taxon *pseudoeffrenatum*.

Material: 2 specimens: MNHB J 24221, J 24322.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24221	45	53.5	21	15.5	17.4	39	29	33	60 40	25 29
MNHB J 24322	32	56	21	13.5	18.2	38	24	33	60 40	28 33

Table 56. Dimensions of *Ataxioceras (Schneidia) geniculatum* Wegele.

Ataxioceras (Schneidia) cf. *geniculatum* Wegele, 1929 [m]
Fig. 130; table 57

Description: The glauconitic, carbonate internal mould of MNHB J 24276 is septate to the diameter of 31 mm. The last septa are not approximated. The body chamber occupies three fourths of the last whorl. The peristome is not preserved. The whorl section is high-trapezoidal with a rounded siphonal side. The primary ribs begin at the umbilical suture line. They swing back on the umbilical wall and margin. They are straight on the whorl sides and lean 11–15° forward. The point of division of the primary ribs into secondaries varies between somewhat below and slightly above half of the whorl height. The mode of division is polyplocal and polygyrate. There are four to five secondary ribs per primary. The secondary ribs lean a little more forward than the primaries and form a proconvex arc on

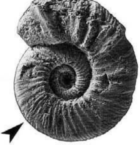


Fig. 130. *Ataxioceras (Schneidia)* cf. *geniculatum* Wegele, MNHB J 24276.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

the siphonal side. There are four deep constrictions on the body chamber beginning at the diameter of 38 mm. The last whorl covers the preceding one by about a third.

Affinities: Ataxioceras (Schneidia) cf. *geniculatum* resembles *Ataxioceras (Schneidia) geniculatum* in the size of the phragmocone. But the umbilicus of MNHB J 24276 cf. *geniculatum* is wider at the diameter of 45 mm than in *Ataxioceras (Schneidia) geniculatum* J 24322 at the corresponding diameter. The point of division of primary into secondary ribs is lower down on the whorl sides of J 24276 cf. *geniculatum* than in J 24322 *geniculatum*. There are four secondary ribs per primary at the end of the phragmocone of J 24276 cf. *geniculatum* as compared with two in J 24322 *geniculatum* at the same growth stage.

Material: 1 specimen: MNHB J 24276.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24276	31	41.3	15	9.9	14.1	36	24	34	50 40	29 33

Table 57. Dimensions of *Ataxioceras (Schneidia)* cf. *geniculatum* Wegele.

Ataxioceras (Schneidia) aff. *polyplocum* (Reinecke, 1818) [m]

Fig. 131–132; table 58

1818 *Nautilus polyplocus* – Reinecke, p. 61, pl. 2, fig. 13–14.

1961 *Ataxioceras (Ataxioceras) polyplocum* (Reinecke) – Geyer, p. 63, table 42, text-fig. 84–85, pl. 11:3–4, with synonymy.

Neotype: Plate 12:8 in Schneid (1944), designated by Geyer (1961:63).

Type locality: Staffelberg near Langheim, Franconia, southern Germany.

Type horizon: Malm γ 2.

Description: The slightly glauconitic, carbonate internal mould of MNHB J 24274 is septate to the diameter of 35 mm. The last two septa are approximated. The body chamber occupies four fifths of the last whorl and is complete with part of the peristome and of a lappet on the reverse of the side represented in figure 131. J 24274 is then a complete adult. The ribbing of the inner whorls is first regular, then becomes irregular on the last half whorl of the phragmocone and on the body chamber. The primary ribs of the phragmocone begin at the umbilical suture line. On the body chamber, they begin in the upper part of the umbilical wall and swing back on the umbilical margin. The primary ribs are straight on the whorl sides and there lean 10–12° forward. They are strongest on the umbilical margin and are attenuated in the middle of the whorl sides. The position of the point of division into two to five secondary ribs is very variable. It is between directly above the umbilical margin and the middle of the whorl sides. The mode of division is polygyrate to polyplocal. The secondary ribs bend markedly forward with respect to the primary ribs and form a proconvex arc on the siphonal side. The whorl height

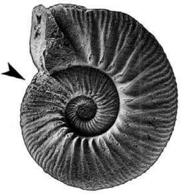


Fig. 131. *Ataxioceras (Schneidia)* aff. *polyplocum* (Reinecke), MNHB J 24274.

Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.

Exchange with H. Holenweg. ×1.

increases only a little on the last whorl, and the umbilical suture line shows an egression.

Affinities: The dimensions of MNHB J 24274 correspond well to those of the neotype at the corresponding growth stage. The umbilicus of the neotype is a little narrower, and the neotype is larger than J 24274.

Material: 1 specimen: MNHB J 24274.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24274	35	57	20	14	22	35	25	38	60 30	26 31

Table 58. Dimensions of *Ataxioceras (Schneidia)* aff. *polyplocum* (Reinecke).

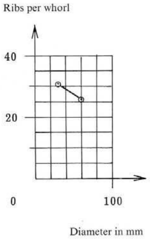


Fig. 132. Rib curve of *Ataxioceras (Schneidia)* aff. *polyplocum* (Reinecke), MNHB J 24274.

Genus *Crussoliceras* Enay, 1959

Type species: Ammonites Crusoliensis Fontannes in Dumortier & Fontannes (1876).

Remarks: The type of the genus *Crussoliceras* is the species *Ammonites Crusoliensis* Fontannes. The holotype of this species was figured by Fontannes in Dumortier & Fontannes (1876, pl. 14:3). The inner whorls of the holotype of *Crussoliceras crusoliense* (Fontannes), to judge of the original drawing, are septate. The fragment of the last whorl is, according to the caption to plate 14:3 by Fontannes, part of the body chamber. The holotype is figured natural size as can be concluded of the photograph of a plaster cast of the holotype that is depicted in Geyer (1961, pl. 5:4). Fontannes stated in the text (p. 97) that the diameter of the ammonite is 104 mm. But these 104 mm are the greatest width of the drawing of the incomplete ammonite, not the diameter. The dimensions in percent given by Fontannes on page 97 are therefore misleading.
Because the drawing of the holotype is natural size, the diameter of the phragmocone is between 78 and about 100 mm. The diameter of the restored, complete shell must then have been at most 150 mm. This is much less than the 300–400 mm stated by Enay (1959:230) to be typical of *Crussoliceras*. Large forms as cited by Enay (1959) have a simple peristome and are probably macroconchs. The shape of the peristome in the type species of *Crussoliceras* is unknown. It cannot be excluded that *Crussoliceras crusoliense* (Fontannes) is a microconch. Enay (1959:230) proposed the generic name *Badenia* for what are small relatives of *Crussoliceras*. The lectotype of the type species, *Badenia wegelei* Enay as figured by Wegele (1929b, pl. 5:4), is so incomplete that it is unfit to be retained as lectotype of a species. The generic name *Badenia* that is based on the species *wegelei* must then be abandoned. The consequence is that *Crussoliceras* is the only genus to which the forms from the lower Baden Member described and figured here (fig. 133–134) can be assigned. It is possible that at least one form figured here (fig. 134b) is a microconch. This and the uncertainty about whether the type species is a macro- or a microconch, would mean that the genus *Crussoliceras* as it is conceived here possibly includes both macro- and microconchs. No *Crussoliceras* with the peristome diagnostic of macro- or microconchs are known from the lower Baden Member of northern Switzerland.

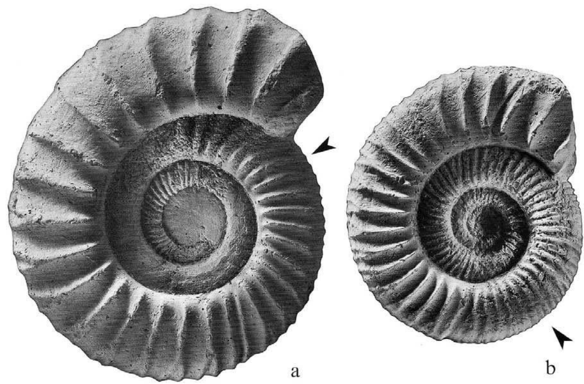


Fig. 133. *Crussoliceras sayni* (Camus & Thieuloy).
a: MNHB J 24341, plastic cast of a specimen without number in the Museum of Natural History, Luzern, provenance unrecorded, to judge of matrix: lowe Baden Member, probably from Mellikon, Canton Aargau;
b: MNHB J 26477, section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1

Crussoliceras sayni (Camus & Thieuloy, 1963)
Fig. 133–134; table 59

1963 *Katroliceras (Crussoliceras) sayni* n.sp. – Camus & Thieuloy, p. 277, fig. 4–5.

Holotype: Figure 5 in Camus & Thieuloy (1963).

Type locality: Montagne de Crussol, Département Ardèche, France.

Type horizon: Streblites tenuilobatus Zone, Kimmeridgian.

Description: The glauconitic, carbonate internal mould of a specimen without number in the Museum of Natural History, Luzern, Switzerland (plastic cast J 24341 in the MNHB, fig. 133a), is septate to the diameter of 74 mm. Almost the entire last whorl is occupied by the body chamber. The body chamber is apparently complete, because the last preserved primary rib has a pronounced forward inclination, and because the last rib is followed by a deep constriction. The peristome is broken off. The whorl section is thick-oval as depicted by Camus & Thieuloy (1963, fig. 4). The whorl height and the whorl thickness are almost equal. The strong primary ribs begin on the rounded umbilical margin above the umbilical suture line. They are straight from the beginning or a little proconcave. They have a slight forward inclination of 4–9° or they are radial. The point of division into two strong secondary ribs is at 70% of the whorl height. There are two simple primary ribs on the body chamber. The secondary ribs have a somewhat stronger forward inclination than the primaries and form a proconvex arc on the siphonal side. The last whorl covers the preceding whorl by about 20%.

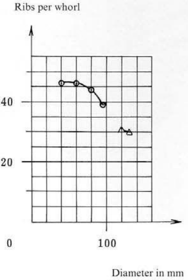


Fig. 134. Rib curves of *Crussoliceras sayni* (Camus & Thieuloy).
Circles: MNHB J 26477;
triangles: MNHB J 24341.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24341	74	119	35.7	-	56.4	30	-	47	130 120	30 31
MNHB J 26477	68	86	25.4	27	40.5	30	31	47	95 80 60 40	39 44 46 46

Table 59. Dimensions of *Crussoliceras sayni* (Camus & Thieuloy).

Affinities: The dimensions, the whorl section and the ribbing of MNHB J 24341 compare very well with the holotype which is incomplete. Camus & Thieuloy (1963:278) mentioned another representative of their new taxon which has a diameter of 160 mm and is complete. This specimen is estimated to be about half a whorl larger than J 24341. The size of J 24341 is then compatible with the taxon by Camus & Thieuloy (1963). *Crussoliceras tenuicostatum* Geyer is similar, but it is more evolute and can have tripartite ribs on the body chamber.

Material: 2 specimens: MNHB J 24341 (plastic cast), J 26477.

Crussoliceras tenuicostatum (Geyer, 1961)
Fig. 135; table 60

1961 *Katroliceras (Crussoliceras) tenuicostatum* n.sp. – Geyer, p. 44, text-fig. 43c, text-fig. 52, pl. 4:3, 5, pl. 5:3.

Holotype: Plate 5:3 in Geyer (1961).

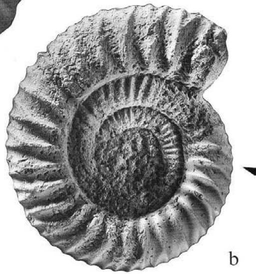
Type locality: Unrecorded, Swabian Alb, southern Germany.

Type horizon: Weisser Jura, upper γ.

Description: The glauconitic, carbonate internal mould of MNHB J 26475 is septate to the diameter of 85 mm. Three quarters of the last whorl are occupied by the body chamber. The phragmocone is flattened and is only partly preserved. The primary ribs of the inner whorls are straight and radial. Some primary ribs of the body chamber have a slight backward inclination. On the body chamber, the primary ribs first split into two, then into three secondary ribs. The fine secondary ribs are arranged on high bulges of the siphonal side. The smaller specimen J 26472 (fig. 135b) is septate to the diameter of 57 mm. More than three quarters of its last whorl are occupied by the body chamber. The whorls of this specimen are rounded-depressed.

Affinities: The large specimen MNHB J 26475 (fig. 135a) is diagenetically deformed. The phragmocone is flattened and the last part of the body chamber is compressed by compaction. Nevertheless, the dimensions of J 26475 agree fairly well with those given in table 23 by Geyer (1961). 41 primary ribs can be counted on the inner whorls of J 26475 at the diameter of 60 mm. At the diameter of 140 mm there are about 28 primary ribs per whorl. This is more than in the holotype that has 24 ribs per whorl at the diameter of 130 mm (counted on the photograph in Geyer, 1961, pl. 5:3). But the configuration of the ribs on the body chamber of J 26475 agrees well with the draw-

a



b

Fig. 135. *Crussoliceras tenuicostatum* (Geyer).
a: MNHB J 26475;
b: MNHB J 26472.
Both section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Fig. 136. *Garnierisphinctes* n.sp., MNHB J 24344.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. A. Villa. ×1.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26475	85	139	43.4	-	69.3	31	-	50	140 60	28 41
MNHB J 26472	57	80.4	22	28.2	41.3	27	35	51	90 80	29 31

Table 60. Dimensions of *Crussoliceras tenuicostatum* (Geyer).

ing of figure 52 in Geyer (1961). The ribbing of the smaller specimen J 26472 (fig. 135b) is looser than that of the similar form as figured by Geyer (1961, pl. 4:3). Moreover, the phragmocone of J 26472 has a diameter of only 57 mm as compared with 85 mm in J 26475. It cannot be established whether the last septa of the smaller specimen J 26472 are approximated or not. This specimen (fig. 135b) is presumed to be juvenile and conspecific with the apparently near-complete J 26475 (fig. 135a). There is some resemblance between the inner whorls of *Crussoliceras tenuicostatum* (Geyer), figure 135b, and *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele), figure 86, that occur in the same bed at Mellikon. However, the body chamber of *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele) is compressed, not depressed as in the inner whorls of *Crussoliceras tenuicostatum* (Geyer). *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele) has tripartite ribs already at the diameter of 70 mm, at a stage where there are only dichotome ribs in *Crussoliceras tenuicostatum* (Geyer). *Orthosphinctes (Orthosphinctes) postcolubrinus* (Wegele) grows to a lesser size than *Crussoliceras tenuicostatum* (Geyer).

Material: 2 specimens: MNHB J 26472, J 26475.

Genus *Garnierisphinctes* Enay, 1959

Type species: Ammonites garnieri Fontannes in Dumortier & Fontannes (1876).

Garnierisphinctes n.sp.
Fig. 136–137; table 61

Description: The glauconitic, carbonate internal mould of MNHB J 24344 is septate to the diameter of ca. 140 mm. Three quarters of the last whorl are occupied by the body chamber. Only one side of the steinkern is preserved, but nevertheless it can be observed that the whorl section is compressed, and that the whorl sides are almost flat and convergent towards the siphonal side. The siphonal side is rounded. The primary ribs begin on the umbilical margin. The lower part of the umbilical wall is smooth. The primary ribs of the phragmocone are straight from the beginning and are mostly radial. The maximum forward inclination of the primaries is 5°. The point of division into three secondary ribs is blurred at the end of the phragmocone. No secondary ribs can be seen on inner whorls. The primary ribs of the body chamber swing slightly back on the umbilical margin. On the body chamber there are first two secondary ribs per primary. Then, at the diameter of 180 mm, the secondary ribs vanish. From there on the primary ribs end in broad, low tubercles at the siphonal margin. The last whorl covers the preceding one by about a third.

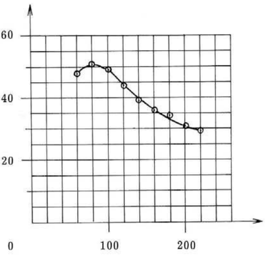


Fig. 137. Rib curve of *Garnierisphinctes* n.sp., MNHB J 24344.

Affinities: Katroliceras (Torquatisphinctes) melliconense Geyer (1961) has similar dimensions and a comparable number of primary ribs per whorl (Geyer, 1961, table 30). The whorl section of *melliconense* Geyer also resembles that of *Garnierisphinctes* n.sp. MNHB J 24344 (see Geyer, 1961, fig. 42c). But the point of division of the primary ribs in Geyer's taxon is distinct, and there are as a rule only two secondary ribs per primary at the diameters between 120 and 130 mm. At this stage, there are three secondary ribs per primary in J 24344, and the point of division is indistinct. To judge of plate 3:2 in Geyer (1961), the holotype of *melliconense* is septate to the diameter of only about 100 mm as compared with ca. 140 mm in J 24344. *Garnierisphinctes* n.sp. is then at least about half a whorl larger than *Katroliceras (Torquatisphinctes) melliconense* Geyer and is probably not conspecific with Geyer's taxon.
Contini & Hantzpergue (1975, pl. 5:1) figured a similar form with tripartite ribs under the name *Crussoliceras (M. Badenia) aceroides* (Geyer). But the primary ribs in this form that is kept in the Musée de Montbéliard, France, are less crowded than in J 24344, and they are proconcave, not straight. The whorls of the French specimen are much thicker than the compressed whorls of J 24344 (see Contini & Hantzpergue, 1975, pl. 2a).

Material: 1 specimen: MNHB J 24344.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 24344	140	183	54.6	-	85.1	30	-	47	220 200 160 120 100 80 60	29 31 36 44 49 51 48

Table 61. Dimensions of *Garnierisphinctes* n.sp.

Fig. 138. *Pachypictonia indicatoria* Schneid, MNHB J 32832.
Section RG 70, large quarry, Mellikon, Canton Aargau, to judge of the matrix: out of bed no. 124: lower Baden Member.
Coll. F. Leuthardt. ×1.

Family Aulacostephanidae Spath, 1924

Subfamily Pictoniinae Spath, 1924

Genus *Pachypictonia* Schneid, 1940

Type species: Pictonia (Pachypictonia) indicatoria Schneid, 1940.

Pachypictonia indicatoria Schneid, 1940

Fig. 138; table 62

1940 *Pictonia (Pachypictonia) indicatoria* n.sp. – Schneid, p. 90, pl. 8(4):1–3.
1957 *Pachypictonia indicatoria* Schneid – Arkell in Arkell et al., p. 324, fig. 416:4.
1973 *Pachypictonia indicatoria* Schneid – Contini & Hantzpergue, p. 166, pl. 6:1.

Holotype: Plate 8(4):1 in Schneid (1940), designated as "Lektotyp" by Schneid (1940:91).

Type locality: Tiefenellern, northern Franconia, southern Germany.

Type horizon: Malm γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 32832 (fig. 138) is wholly septate. The whorl section is oval. The primary ribs of the innermost whorls are proconcave and radial. They have almost sharp edges. From the diameter of 80 mm on the ribs become blunt, swollen and distant. The first cuneiform primary rib appears at the diameter of 150 mm. The secondary ribs disappear before the diameter of 110 mm. The siphonal side of the last whorl of J 32832 is smooth. The last whorl covers the preceding one by 37%. Another specimen which is badly preserved, J 26470 (not figured), is septate to the diameter of 258 mm. One fourth of its last whorl is occupied by the body chamber. Based on this specimen it can be estimated that this taxon grew to a maximum diameter of about 370 mm.

Affinities: Pictonia (Pachypictonia) indicatoria Schneid (1940, pl. 8(4):1) is a wholly septate nucleus with a diameter of 252 mm according to Schneid (1940:90) or 265 mm as measured on figure 1 in plate 8(4) by Schneid (1940), respectively. The dimensions given by Schneid (1940:90) compare well with those of the two specimens listed in table 62 of this study. Schneid (1940:90) counted 22 primary ribs on an inner whorl of the holotype, and there are eleven on the last whorl of it. Eleven primary ribs can be counted on half a whorl of J 32832 at the diameter of 55 mm. There are ten primary ribs on the last whorl of J 26470. The whorl section is oval at the whorl height of 70 mm both in the holotype and in J 26470, but it becomes rounded-quadrate at the end of the last whorl of J 26470.

Material: 2 specimens: MNHB J 26470, J 32832.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26470	258	260	76	76	120	29	29	46	290	10
MNHB J 32832	Nu	173	50	45.5	83	29	26	48	190	14

Table 62. Dimensions of *Pachypictonia indicatoria* Schneid.

Pachypictonia divergens Schneid, 1940

Fig. 139–142; table 63

1940 *Pictonia (Pachypictonia) divergens* n.sp. – Schneid, p. 99, pl. 12(8):1, non 2–4.

Lectotype: Plate 12(8):1 in Schneid (1940), designated here.

Type locality: Zeegendorf, northern Franconia, southern Germany.

Type horizon: Malm γ.

Description: The glauconitic, carbonate internal mould of MNHB J 26468 (figure 139) is septate to the diameter of 343 mm. One fourth of the last whorl is occupied by the body chamber. The section of the body chamber is thick-oval. There are low and distant, cuneiform ribs at the sides of the body chamber. The siphonal side is smooth. The smallest representative of the taxon in the collection of R. & S. Gygi is J 24360 (fig. 141). This has a diameter of 240 mm and is wholly septate. The section of the last whorl is oval. There are low, radial primary ribs on the side of the innermost whorls. 20 ribs can be counted at the umbilical width of 25 mm. The ribs fade away at the umbilical width of 33 mm that corresponds to a diameter estimated at 110 mm. From there on there are neither primary nor secondary ribs. The larger specimen J 24196 with a maximum diameter of 340 mm (fig. 140) is probably also wholly septate. There are 20 weak primary ribs at the umbilical width of 25 mm. The ribs vanish at the umbilical width of 42 mm that corresponds to a diameter estimated at 170 mm. From there on the whorls are smooth until at the diameter of 335 mm where a low wave appears on the whorl side. Such a wave first appears on the larger J 26468 (fig. 139) at the diameter of 310 mm as an initial stage to the cuneiform ribs on the body chamber of this specimen.
Specimen J 32811 (fig. 142) is septate to the diameter of 372 mm. A small part of the body chamber is preserved. The last two septa are approximated and indicate that the specimen is adult. J 32811 has a much narrower umbilicus than that of the lectotype at the corresponding growth stage. At the diameter of 375 mm, the umbilicus of J 32811 has a width of only 32% of the diameter as compared with 37% of the whorl height. The specimen is involute at this growth stage. But the last half whorl of the phragmocone has a distinct egression that was calculated at 1.5. It is therefore possible or even probable that the complete (restored) shell was slightly evolute. There are 16 radial primary ribs per whorl with relatively sharp edges at the umbilical width of ca. 20 mm. Then follows a smooth whorl. The first low wave appears on the side of the last whorl at the diameter of 280 mm. There are three such waves on the last half whorl.

Affinities: According to Schneid (1940, caption to pl. 12(8):1), the lectotype of *Pachypictonia divergens* is a wholly septate nucleus. J 26468 (fig. 139) is half a whorl larger, and one fourth of its last whorl is occupied by the body chamber. If the body chamber of this specimen is assumed to have been three quarters of the last whorl, then the restored diameter of J 26468 would have been about 480 mm. The diameter of the complete (restored) shell of *Pachypictonia divergens* Schneid J 32920 from the Reuchenette Formation of Olten (not figured) is esti-

Fig. 139. *Pachypictonia divergens* Schneid, MNHB J 26468.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. A. Villa. ×0.5.

Fig. 140. *Pachypictonia divergens* Schneid, MNHB J 24196.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×0.6.

Fig. 141. *Pachypictonia divergens* Schneid, MNHB J 24360.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×0.9.

Fig. 142. *Pachypictonia divergens* Schneid, MNHB J 32811.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. Gygi. ×0.6.

mated at about 500 mm. *Pachypictonia* must then be a giant, macroconch genus.
The swollen, cuneiform ridges on the whorl sides of large *Pachypictonia* seem to be typical of the genus. This is why J 32811 (fig. 142) is assigned to *Pachypictonia* in spite of its narrow umbilicus at the diameter of 375 mm. This specimen is at this time considered to be an involute morphotype of *Pachypictonia divergens* Schneid even though the restored shell that probably had a diameter of more than 500 mm must have been evolute as is indicated by the significant egression. The dimensions and the whorl section of the specimen are very similar to those of *Involuticeras limbatum* (Schneid) J 32815 (not figured, see table 69) at the corresponding growth stage. It can be read from Schneid (1940, captions to pl. 16(12):1–2), that in some cases it is not easy to distinguish *Pachypictonia* from *Involuticeras*. But the representatives of *Involuticeras* that have been figured to date are of lesser size than *Pachypictonia* from Switzerland.
The identification of the involute, but adult J 32811 (fig. 142) as *Pachypictonia* might be challenged. The interpretation of the taxon as given in table 63 implies that adult *Pachypictonia* can be both evolute and involute at the growth stage of 350 mm. The specific name *divergens* by Schneid (1940) would indeed be appropriate, if this interpretation be correct.
Several questions cannot be answered at this time. It is unknown to what size *Involuticeras* grew. No *Involuticeras* the size of J 32811 (fig. 142) was previously figured. The inner whorls of *Pachypictonia* are not known with any degree of certainty. To judge of J 24360 (fig. 141), they are involute in *Pachypictonia divergens* Schneid. On the other hand, the inner whorls of *Pachypictonia* n.sp. J 26469 (fig. 143) are certainly evolute. This casts doubt on whether the genus *Pachypictonia* as it is conceived here is in reality a single taxonomic unit. The concept of *Pachypictonia* adopted here is then tentative. More and better material is needed for a certain distinction of *Pachypictonia* from *Involuticeras*.

Material: 8 specimens: MNHB J 24196, J 24198, J 24360, J 26463, J 26468, J 26514, J 32811, J 32920.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 32811	372	375	138	-	120	37	-	32	100?	16
MNHB J 26468	343	343	103	~105	150	30	~31	44	-	-
MNHB J 32920	~340	~429	~133	-	178	31	-	41	-	-
MNHB J 24196	Nu	327	110	82	122	34	25	37	100?	20
MNHB J 26463	Nu	319	123	-	102	39	-	32	110?	21
MNHB J 24198	Nu	291	101	-	122	35	-	42	-	-
MNHB J 26514	Nu	281	99	-	107	35	-	38	-	-
MNHB J 24360	Nu	240	88	-	84	37	-	35	100?	20

Table 63. Dimensions of *Pachypictonia divergens* Schneid.

Pachypictonia n.sp.

Fig. 143; table 64

? 1968 *Pomerania (Pachypictonia) albinea* (Oppel) – Kutek, p. 564, pl. 8:3.

Description: The glauconitic, carbonate internal mould of MNHB J 26469 is septate to the diameter of ca. 367 mm. The last septa are approximated, and a small fragment of the body chamber is preserved. From this it can be estimated that the complete shell must have had a diameter of about 450 mm. The section of the inner whorls is thick-oval. There are only traces of primary ribs on the inner whorls that appear to be smooth. Broad and distant, cuneiform ribs are at the preserved side of the last whorl. The siphonal side of the last whorl is smooth.

Affinities: Pachypictonia n.sp. resembles *Pachypictonia divergens* Schneid (see above) in the adult size, in the almost smooth whorls at middle growth stages and in the cuneiform gerontic ribs. But *Pachypictonia* n.sp. has so much more evolute inner whorls that the two forms can hardly be conspecific. *Pomerania (Pachypictonia) albinea* (Oppel) in Kutek (1968, pl. 8:3) has cuneiform ribs on the last whorl and an umbilical width that is close to that of *Pachypictonia* n.sp. figured here. The two forms may be conspecific.

Material: 1 specimen: MNHB J 26469.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26469	367	367	93	-	183	25	-	50	-	-

Table 64. Approximate dimensions of *Pachypictonia* n.sp.

Genus *Ringsteadia* Salfeld, 1913

Type species: Ammonites pseudocordatus Blake & Hudleston, 1877.

Remarks: Salfeld (1917:70) characterized the genus *Ringsteadia* as having a narrow umbilicus, and wrote that the descent of the whorl sides to the umbilical suture line was rounded and had a gentle inclination. The gerontic stages are smooth. The point of division of the primary ribs is blurred and is above half of the whorl height. There are two to five secondary ribs per primary. On page 74 Salfeld stated that *Ringsteadia* occurs in the uppermost Oxfordian. This was recently confirmed by J.H. Callomon (oral communication) for England. Salfeld assigned the similar *Ammonites tenuiplexus* Quenstedt in the Lower Kimmeridgian of southern Germany to *Involuticeras*. However, Schneid (1939) and Geyer (1961) were of the opinion that several taxa from the Lower Kimmeridgian of southern Germany were to be allocated in the genus *Ringsteadia*. If a rounded umbilical wall that touches the umbilical suture line at an acute angle, a narrow umbilicus and a smooth gerontic stage are rated to be characteristic of the genus *Ringsteadia*, then the question must indeed be asked whether Geyer (1961)

Fig. 143. *Pachypictonia* n.sp., MNHB J 26469.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×0.7.

was right to assign *Ammonites (?Perisphinctes) Weinlandi* Fischer (1913) from the Weisser Jura γ (Platynota Zone) of southern Germany to the genus *Ringsteadia.* The ammonite MNHB J 24308 (fig. 144) from the lower Baden Member of Mellikon, Canton Aargau, is therefore tentatively assigned to the genus *Ringsteadia.*

Ringsteadia? cf. *weinlandi* (Fischer, 1913)

Fig. 144; table 65

cf.v 1913 *Ammonites (?Perisphinctes) Weinlandi* n.sp. – Fischer, p. 52, pl. 5:15.
cf.v 1961 *Ringsteadia (Vineta) weinlandi* (Fischer) – Geyer, p. 128, pl. 22:5–6.
non 1966 *Ringsteadia (Vineta)* cf. *weinlandi* (Fischer) – Enay, p. 566, pl. 40:1.

Holotype: University of Tübingen, Museum für Geologie und Paläontologie, plate 5:15 in Fischer (1913).

Type locality: Tieringen, Württemberg, southern Germany.

Type horizon: Weisser Jura γ, Reineckianus (= Platynota) Zone.

Description: The glauconitic, carbonate internal mould of MNHB J 24308 is septate to the diameter of 134 mm. A small part of the body chamber is preserved. The whorl section is high-oval with a relatively broadly rounded siphonal side. The umbilical wall of the inner whorls touches the preceding whorls at a right angle, but on the last whorl its inclination diminishes gradually to about 45° at the beginning of the body chamber. The primary ribs of the inner whorls are distinct and radial. There are 24 primary ribs per whorl at the diameter of 100 mm. On the last whorl the primary ribs are attenuated and are faint on the body chamber. They fade away entirely in the middle of the whorl sides. There are five weak and blunt secondary ribs per primary on the phragmocone. The secondary ribs vanish at the diameter of 130 mm near the end of the

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
Tübingen, holotype	Nu	151	72	44	25	48	29	17	100	25
MNHB J 24308	138	130	61	-	24	47	-	19	140 120 100	20 20 24

Table 65. Dimensions of *Ringsteadia*? cf. *weinlandi* (Fischer).

Fig. 144. *Ringsteadia*? cf. *weinlandi* (Fischer), MNHB J 24308.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. A. Villa. ×1.

phragmocone. The last whorl covers the preceding one by about 70%.

Affinities: The dimensions, the section of the last whorl and the number of primary ribs per whorl of MNHB J 24308 are similar to those of the holotype of *Ringsteadia*? *weinlandi* (Fischer). Another similarity between the two specimens is the deep umbilicus of the inner whorls and the gentle descent of the whorl sides to the umbilical suture line on the last whorl. But there are more and finer secondary ribs per primary in J 24308 than in the holotype of *weinlandi*. J 24308 might be younger than the holotype of *weinlandi*, because most ammonites found in bed no. 124 of section RG 70 at Mellikon, Canton Aargau, are of the Hypselocyclum Chron. J 24308 is therefore assigned with reservation to the taxon *weinlandi* (Fischer).

Subfamily Aulacostephaninae Spath, 1924

Genus *Rasenia* Salfeld, 1913

Type species: Rasenia anglica Geyer, 1961, nom.nov. for *Rasenia involuta* Spath, 1935.

Remarks: Geyer (1961:86) renamed the type species *Rasenia involuta* Spath, 1935, *Rasenia anglica* nom.nov. by reference to the International Code of Zoological Nomenclature. Hantzpergue (1989:229) ignored this. Geyer (1961:93) drew attention to the fact that the holotype of *Rasenia involuta* Spath = *Rasenia anglica* Geyer had a diameter of less than 40 mm. Hantzpergue (1989:230) remarked like Spath (1935:38–40, as cited from Geyer, 1961), that *Rasenia* Salfeld, 1913, is an element of the subboreal faunal province. Hantzpergue was of the opinion that *Rasenia* as described by Geyer (1961) from southern Germany and northern Switzerland belong to the genus *Eurasenia* Geyer, 1961. Hantzpergue (1989:259) included the probably macroconch *Involuticeras* Salfeld, 1913 (see Geyer, 1961:91), and the microconch *Prorasenia* Schindewolf, 1925 (see Geyer, 1961:92), in *Eurasenia* and interpreted the microconch *Rasenioides* Schindewolf, 1925, as a separate genus that includes both macro- and microconchs (Hantzpergue, 1989:271). Hantzpergue cannot be followed in this.
It is as yet uncertain whether *Prorasenia* is the microconch of *Eurasenia* and possibly of *Pachypictonia* or whether *Rasenioides* is the microconch of *Involuticeras* (see Geyer, 1961:92) and maybe of *Balticeras*. The material available for this study is insufficient for a decision on these problems. Consequently, the genera and subgenera mentioned above are kept separate in this study and are treated as if they were all genera.

Fig. 145. *Eurasenia balteata* (Schneid), MNHB J 26453.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Genus *Eurasenia* Geyer, 1961

Type species: Ammonites rolandi Oppel, 1863.

Eurasenia balteata (Schneid, 1939)

Fig. 145–146; table 66

1961 *Rasenia (Eurasenia) balteata* Schneid (1939) – Geyer, p. 93, pl. 18:1, with synonymy.
1961 *Rasenia (Eurasenia) trifurcata* (Reinecke) – Geyer, p. 93, pl. 19:3, pl. 22:4, non pl. 1:7.
1973 *Rasenia balteata* Schneid – Contini & Hantzpergue, p. 168, pl. 5:2.

Holotype: Plate 7(3):3 in Schneid (1939).

Type locality: Staffelberg near Staffelstein, northern Franconia, southern Germany.

Type horizon: Malm γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 26453 is septate to the diameter of 111 mm. A small part of the body chamber is preserved. The whorl section at the end of the phragmocone is thick-oval and depressed. The primary ribs begin on the lower part of the rounded umbilical margin. The vertical umbilical wall is smooth. The primary ribs of the inner whorls have a forward inclination of ca. 10°. On the last whorl they are radial. They are high and blunt. At 40–45% of the whorl height they split into two strong and blunt secondary ribs. One intercalated secondary rib is associated with every primary rib. The secondary ribs have the same direction as the primaries, but they are not as strong as the primary ribs. The secondaries are not attenuated at the siphonal side. The last whorl covers the preceding one by 52%.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26453	111	93	33.8	43	34.1	36	46	37	110 80 60 40	15 15 16 15

Table 66. Dimensions of *Eurasenia balteata* (Schneid).

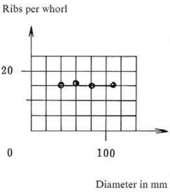


Fig. 146. Rib curve of *Eurasenia balteata* (Schneid), MNHB J 26453.

Affinities: Eurasenia balteata (Schneid) resembles *Eurasenia trifurcata* (Reinecke). The main difference is that Reinecke's taxon has four secondary ribs per primary already at the diameter of ca. 50 mm, and that its whorls are thicker, to judge of the drawings by Reinecke (1818, pl. 5:49–50). MNHB J 26453 differs from the holotype of *Eurasenia balteata* (Schneid) in that it is slightly less evolute. The dimensions of the holotype given by Schneid (1939:134) do not agree with those that can be measured on the photograph of the type (pl. 7(3):3). *Eurasenia balteata* (Schneid) is very similar to inner whorls of the much larger *Eurasenia gemina* (Schneid) (compare with MNHB J 26520, fig. 77).

Material: 1 specimen: MNHB J 26453.

Eurasenia rolandi (Oppel, 1863)

Fig. 147–148; table 67

1863 *Ammonites Rolandi* Opp. – Oppel, p. 239, pl. 67:3.
1939 *Rasenia Rolandi* (Oppel) – Schneid, p. 151, pl. 6(10):1 (holotype photographically refigured).
1961 *Rasenia (Eurasenia) rolandi* (Oppel) – Geyer, p. 95, pl. 21:2, with synonymy.
1968 *Rasenia (Eurasenia) rolandi* (Oppel) – Kutek, p. 554, pl. 6:2.

Holotype: Plate 67:3 in Oppel (1863), refigured photographically by Schneid (1939, pl. 6(10):1).

Type locality: Pegnitz, Franconia, southern Germany.

Type horizon: Unknown.

Description: The glauconitic, carbonate internal mould of MNHB J 26451 is septate to the diameter of 75 mm. Three fourths of the last whorl are occupied by the body chamber. The whorl section is oval. The primary ribs begin on the umbilical margin. The vertical umbilical wall is smooth. The primary ribs are straight and radial and are strongest in the lowermost part of the whorl sides. The primary ribs are strong on the inner whorls and become weaker on the body chamber. They split at 40% of the whorl height into three to four secondary ribs that are not attenuated along the siphonal line. The secondary ribs have the same direction as the primaries and are strong. The last whorl covers the preceding one by 60%.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26451	75	101	47	46	24	47	46	24	110 80 60	17 17 17

Table 67. Dimensions of *Eurasenia rolandi* (Oppel).

Fig. 147. *Eurasenia rolandi* (Oppel), MNHB J 26451.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

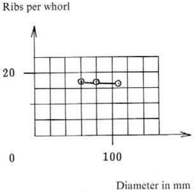


Fig. 148. Rib curve of *Eurasenia rolandi* (Oppel), MNHB J 26451.

Affinities: MNHB J 26451 differs from the holotype in its umbilicus that is considerably narrower. There are somewhat more secondary ribs per primary in J 26451 than in the holotype that has three secondaries per primary. There are 20 primary ribs on the last whorl of the holotype as compared with 17 in J 26451. According to Oppel (1863:239), the holotype is a wholly septate nucleus with a diameter of 96 mm. J 26451 is then either of smaller size or immature.

Material: 1 specimen: MNHB J 26451.

Eurasenia gothica (Schneid, 1939)

Fig. 149–150; table 68

1939 *Ringsteadia gothica* n.sp. – Schneid, p. 168, pl. 11(15):2, 4, non 3.
1961 *Rasenia (Eurasenia) gothica* (Schneid) – Geyer, p. 97, pl. 18:6, with synonymy.
non 1973 *Ringsteadia gothica* Schneid – Contini & Hantzpergue, p. 164, pl. 1:h, pl. 5:1.

Holotype: Plate 11(15):2 in Schneid (1939), designated as "Lekto-Typ" by Schneid.

Type locality: Tiefenellern, Franconia, southern Germany.

Type horizon: Malm γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 26457 is wholly septate. The whorl section is oval. The lower part of the rounded umbilical wall is smooth. The primary ribs begin at the umbilical margin. Some of them swing back on the umbilical margin, but the majority of them is straight from the beginning and radial. The primary ribs are strongest at the base of the whorl sides and then become weak in the middle of the whorl sides. The primary ribs split at less than 50% of the whorl height into three to four secondary ribs. The point of division is blurred. The secondary ribs are weak and fade away on the siphonal side from the diameter of 140 mm. They have the same direction as the primaries. The last whorl covers the preceding one by 55%.

Individual labelling of specimen	Ph mm	Dimensions, mm				in % of Dm			Ur/whorl	
		Dm	Wh	Wt	Um	Wh	Wt	Um	Dm	n
MNHB J 26457	Nu	154	61	48	50	40	31	32	180 160 120 100 80 60	24 23 22 22 22 20

Table 68. Dimensions of *Eurasenia gothica* (Schneid).

Fig. 149. *Eurasenia gothica* (Schneid), MNHB J 26457.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Affinities: The dimensions, the whorl section and the ribbing of MNHB J 26457 compare very well with the holotype. The size of full-grown adults of this taxon is unknown. An ill-preserved, wholly septate specimen (MNHB J 32924) that the author found in 1962 also in bed no. 124 of section RG 70 at Mellikon has a diameter of 315 mm. The incomplete nucleus can be assigned with reservation to *Eurasenia gothica* (Schneid). If this be correct, it would mean that adult *Eurasenia gothica* grew to giant size with a diameter in excess of 400 mm. This is much more than the maximum diameter of for instance *Eurasenia balteata* (Schneid) that seems to be of the order of 150 mm. From this the question arises whether the genus *Eurasenia* as it is conceived here is uniform or whether it includes both macroconchs and large microconchs.

Material: 1 specimen: MNHB J 26457.

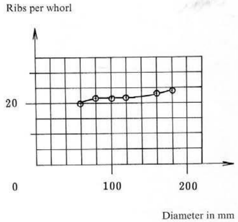


Fig. 150. Rib curve of *Eurasenia gothica* (Schneid), MNHB J 26457.

Genus *Involuticeras* Salfeld, 1913

Type species: Ammonites involutus Quenstedt, 1846.

Remarks: It is probable that *Involuticeras* is closely related both to *Eurasenia* and to *Balticeras*. *Involuticeras* differs from *Eurasenia* in that its primary ribs are weaker and blunter than those of *Eurasenia*. The primary ribs of *Involuticeras* fade away completely in the middle of the whorl sides, whereas they do not fade at all or are only attenuated in the middle of the whorl sides of inner whorls of large *Eurasenia*. *Involuticeras* differs from *Balticeras* in that its primary ribs are somewhat stronger. The very weak primary ribs of the innermost whorls of *Balticeras* (fig. 156) fade away earlier in the course of ontogeny than in *Involuticeras*.

Involuticeras limbatum (Schneid, 1939)

Fig. 151–152; table 69

1939 *Ringsteadia limbata* n.sp. – Schneid, p. 175, pl. 16(12):2.
1961 *Rasenia (Involuticeras) limbata* (Schneid) – Geyer, p. 105, pl. 20:2.

Holotype: Plate 16(12):2 in Schneid (1939).

Type locality: Zeegendorf, Franconia, southern Germany.

Type horizon: Malm γ 2.

Description: The glauconitic, carbonate internal mould of MNHB J 24359 (fig. 152) is wholly septate. The whorl section is oval. The umbilical wall is vertical and smooth. The primary ribs begin at the rounded umbilical margin where they swing back. They are weak, blunt and radial. The primary ribs fade away completely in the middle of the whorl sides. They fade also in the course of ontogeny: The umbilical margin of J 26464 becomes smooth at the diameter of 165 mm (fig. 151). There are three weak and radial secondary ribs per primary in J 24359 (fig. 152) that are not attenuated along the siphonal line. The secondary ribs fade entirely in the course of ontogeny. The siphonal side of J 26464 is smooth at the latest from the diameter of 110 mm. The last whorl of J 24359 covers the preceding one by 60%.

Affinities: The holotype of Schneid (1939:175, pl. 16(12):2) is a wholly septate nucleus. MNHB J 32815 (not figured) is still septate at the diameter of ca. 260 mm. Adults of this taxon must therefore be very large or could be even giants. Inner whorls of *Involuticeras limbatum* (Schneid) are very similar to *Involuticeras involutum* (Quenstedt). The difference between the two taxa is that there are somewhat more secondary ribs per primary in *Involuticeras involutum* and that the secondary ribs of inner whorls of *Involuticeras involutum* bend forward with respect to the primary ribs. The secondary ribs of *Involuticeras involutum* form a proconvex arc on the siphonal side.

Material: 3 specimens: MNHB J 24359, J 26464, J 32815.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26464	Nu	203	85	56	52	42	28	26	-	-
MNHB J 24359	Nu	105	47	-	20.7	45	-	20	-	-

Table 69. Dimensions of *Involuticeras limbatum* (Schneid).

Genus *Balticeras* Dohm, 1925

Type species: Balticeras Pommerania Dohm, 1925.

Remark: Dohm (1925:25) first called the genus *Baltia*. Then, on page 34 and in the captions to the plates, he wrote *Balticeras*. Arkell in Arkell et al. (1957:L 324) selected *Balticeras* to be the valid name of the genus.

Fig. 151. *Involuticeras limbatum* (Schneid), MNHB J 26464.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

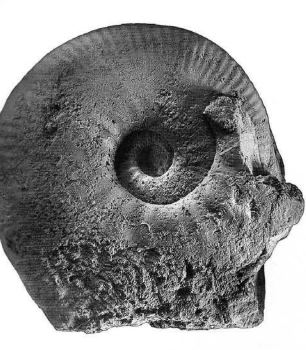


Fig. 152. *Involuticeras limbatum* (Schneid), MNHB J 24359.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Balticeras pommerania Dohm, 1925
Fig. 153–156; table 70

v* 1925 *Balticeras Pommerania* n.sp. – Dohm, p. 34, pl. 5:1–3.
v 1957 *Balticeras pommerania* Dohm – Arkell in Arkell et al., p. L 324, fig. 416/1a–b.

Holotype: University of Greifswald, Geologische Landessammlung, without number, plate 5:2 in Dohm (1925).

Type locality: Quarry near Czarnoglowy (= former German Zarnglaff), Poland.

Type horizon: Upper Jurassic.

Description: The glauconitic, carbonate internal mould of MNHB J 24181 (fig. 153) is septate to the diameter of 390 mm. Two thirds of the last whorl are occupied by the body chamber. The arched line that touches the umbilical suture line at the end of the body chamber might be part of the peristome. If this be the case, the body chamber would be complete. The whorl section is oval (fig. 154). The umbilical wall is vertical and smooth on the inner whorls and is even slightly overhanging in two other specimens (J 26466, fig. 155, and J 32925, not figured). No primary ribs can be seen in J 24181 (fig. 153) that is smooth from the innermost visible whorls. Traces of ribs are visible on the fragment of inner whorls J 26459 (fig. 156). Very weak and blunt primary ribs can just be discerned on the umbilical margin until the umbilical width of 20 mm in this specimen. The middle of the whorl sides are smooth at this ontogenetical stage. Very faint secondary ribs bending slightly forward can be seen at the right side of figure 156. Somewhat stronger secondary ribs are visible on the innermost preserved whorl of the badly preserved, but probably adult and nearly complete J 24354 (not figured) and on the innermost whorl of J 26458 (not figured). Both primary and secondary ribs fade ontogenetically away entirely at the diameter of 90 mm, this is to say very early in the course of ontogeny. The last whorl of J 26466 (fig. 155) covers the preceding one by 60% at the end of the phragmocone. At the presumed peristome of J 24181 (fig. 153), the last whorl covers the preceding one by less than 50% (estimated). This is an indication that there is an egression of the umbilical suture line on the last whorl. Indeed, the egression as calculated according to Gygi (2001:14) is 1.33 at the end of the last whorl of J 24181.

Affinities: The holotype of *Balticeras pommerania* Dohm is a wholly septate nucleus with a diameter of 198 mm as measured by the author. The last whorl of the holotype covers the preceding whorl by 62%. This is similar to J 26466 in which the covering is 60% (fig. 155). *Balticeras pommerania* Dohm was so far known only from Czarnoglowy, Poland. The new material found in Switzerland proves that *Balticeras pommerania* grew to giant size approaching a diameter of 600 mm. The dimensions and the whorl section of the taxon are similar to those of *Involuticeras limbatum* (Schneid). But the ribbing of *Balticeras pommerania* is weaker and fades away earlier in ontogeny than in *Involuticeras limbatum*. The secondary ribs of *Balticeras pommerania* do not bend forward as much as those of *Involuticeras involutum* (Quenstedt). The only previously figured specimen that may be an inner whorl of *Balticeras pommerania* is *Rasenia rimulosa* Schneid (1939:150, pl. 9(5):15). The egression of the umbilical suture line in adult *Balticeras pommerania* with growing diameter can be read from table 70 (percentages of width of umbilicus).

Material: 11 specimens: MNHB J 24181, J 24197, J 24354, J 24355, J 26458, J 26459, J 26465, J 26466, J 32812, J 32813, J 32925. Together with J 32816 (p. 77, fig. 80–81) and an unnumbered specimen, 13 *Balticeras pommerania* have been collected in northern Switzerland.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24181	390	588	197	-	220	34	-	37	-	-
MNHB J 24354	390	491	192	-	162	39	-	33	-	-
MNHB J 26466	375	378	159	-	103	42	-	27	-	-
MNHB J 32812	Nu	262	123	-	48	47	-	18	-	-
MNHB J 24355	Nu	213	101	61	41	47	29	19	-	-
Holotype	Nu	198	95	56	35	48	28	18	-	-
MNHB J 26465	Nu	174	81	-	34	47	-	20	-	-
MNHB J 26459	Nu	101	46	-	21.5	46	-	21	-	-

Table 70. Dimensions of *Balticeras pommerania* Dohm.

Fig. 153. *Balticeras pommerania* Dohm, MNHB J 24181.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member. Small adhering specimen: *Ataxioceras (Parataxioceras) evolutum* Atrops, J 32834.
Coll. A. Villa. ×0.3.

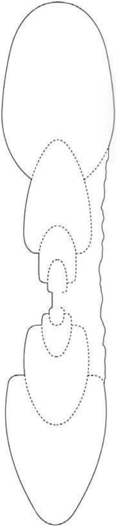


Fig. 154. Cross-section of *Balticeras pommerania* Dohm, MNHB J 24181.
×0.3.

Fig. 155. *Balticeras pommerania* Dohm, MNHB J 26466.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×0.6.

Fig. 156. *Balticeras pommerania* Dohm, MNHB J 26459.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Genus *Prorasenia* Schindewolf, 1925

Type species: Prorasenia Quenstedti Schindewolf, 1926.

Prorasenia stephanoides (Oppel, 1863)
Fig. 157; table 71

1858 *Ammonites anceps albus* – Quenstedt, p. 617, pl. 76:3.
1863 *Ammonites stephanoides* Opp. – Oppel, p. 237, pl. 66:4, non 5.
1876 *Ammonites stephanoides* Oppel – Fontannes in Dumortier & Fontannes, p. 96, pl. 14:2.
non 1877 *Ammonites (Perisphinctes) stephanoides* Oppel – Favre, p. 38, pl. 3:6.
1878 *Ammonites stephanoides* Oppel – de Loriol, p. 84, pl. 13:7–9, non 10.
1887 *Ammonites crenatus* – Quenstedt, p. 873, pl. 94:27–29, 35.
? 1939 *Rasenia stephanoides* Opp. – Schneid, p. 136, pl. 8(4):13.
1961 *Rasenia (Prorasenia) stephanoides* (Oppel) – Geyer, p. 106, pars table 83, non pl. 19:1, ?pl. 21:4.

Lectotype: Plate 66:4 in Oppel (1863), designated by Geyer (1961:106).

Type locality: Area near Boll, Württemberg, southern Germany.

Type horizon: Zone of *Ammonites tenuilobatus*.

Description: The glauconitic, carbonate internal mould of MNHB J 26449 is septate to the diameter of 16 mm. The last

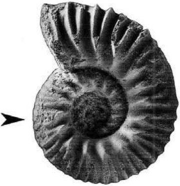


Fig. 157. *Prorasenia stephanoides* (Oppel), MNHB J 26449.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×2.

septa are not approximated. Three quarters of the last whorl are occupied by the body chamber. The section of the inner whorls is very depressed until at the end of the phragmocone. From there on, the whorl height increases more than the whorl thickness, so that the section at the end of the last whorl is only slightly depressed. The primary ribs begin at the umbilical suture line. They are strong and almost radial or have a slight forward inclination. They end in a stubby thorn just below half the whorl height. Three to four secondary ribs issue from there on the phragmocone. On the rear part of the body chamber there are three low and rather blunt secondary ribs per primary. At the end of the body chamber, the number of secondary ribs per primary diminishes to two. The secondary ribs at the end of the body chamber are strong and sharp. The secondary ribs are not interrupted along the siphonal line. They are radial or bend slightly backward.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26449	16	29.4	10.3	-	11.4	35	-	39	30 20	17 15

Table 71. Dimensions of *Prorasenia stephanoides* (Oppel).

Affinities: Oppel (1863:237) stated that most of the body chamber of the lectotype was preserved and that the specimen was adult. It is evident from his further description that the specimen must be mature. MNHB J 26449 is probably also mature to judge of the variation of the whorl section and of the ornamentation on the last whorl. However, this is not confirmed by the last septa of the specimen that are not approximated. According to Oppel, the taxon grows to a maximum diameter of 30 mm. It is therefore improbable that the specimen as figured by Geyer (1961, pl. 19:1) with a diameter of 60 mm belongs to this taxon. J 26449 as figured here is probably the first unambiguous *Prorasenia stephanoides* (Oppel) that has ever been depicted photographically. This is important, because Geyer (1961:106) stated that he could not find the lectotype at München, Germany.

Material: 1 specimen: MNHB J 26449.

Genus *Rasenioides* Schindewolf, 1925

Type species: Nautilus striolaris Reinecke, 1818.

Rasenioides paralepidulus (Schneid, 1939)

Fig. 158a–b; table 72

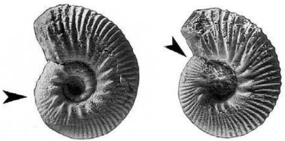
1926 *Prorasenioides* cf. *transitorius* n.sp. – Schindewolf, p. 507, text-fig. 4, pl. 19:4–5.
1939 *Rasenia paralepida* n.sp. – Schneid, p. 146.
1939 *Rasenia paralepidula* n.sp. – Schneid, caption to pl. 5(9):14.
1961 *Rasenia (Rasenioides) paralepida* Schneid – Geyer, p. 114, pl. 5:10, pl. 8:4.

Remark: Schneid (1939:146) first called his new taxon *Rasenia paralepida.* It is evident from the following text that the new name refers to *Ammonites lepidulus* Oppel, 1863. Schneid (1939, caption to pl. 5(9):14) then called the same taxon *Rasenia paralepidula.* Because of this, the specific name *paralepidulus* is used here in contrast to Geyer (1961).

Holotype: Plate 5(9):14 in Schneid (1939).

Type locality: Staffelberg, Franconia, southern Germany.

Type horizon: Malm γ.



a b

Fig. 158. *Rasenioides paralepidulus* (Schneid).
a: MNHB J 24350, road from Wislikofen, Canton Aargau, to Rümikon-Mellikon railway station, Wislikofen; lower Baden Member, coll. H. Hess;
b: MNHB J 26447, section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124; lower Baden Member, coll. R. & S. Gygi.
Both specimens ×2.

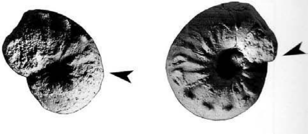
Description: The glauconitic, carbonate internal mould of MNHB J 24350 (fig. 158a) is septate to the diameter of 11 mm. The last three septa are approximated. Three quarters of the last whorl are occupied by the body chamber. The section of the last whorl of the phragmocone is very depressed. On the body chamber the whorl height grows more than the whorl thickness, so that the whorl section is slightly compressed and rounded near the aperture. The vertical umbilical wall of the inner whorls is smooth. The distant primary ribs begin there on the umbilical margin and are short and strong. They have a marked forward inclination. They are strongest at the beginning of the body chamber. They split below half of the whorl height into five secondary ribs on the phragmocone. The secondary ribs are strong, but blunt and radial. Their number per primary rib diminishes from five on the phragmocone to two near the aperture, where their strength is enhanced. In constrast to that, the strength of the primary ribs diminishes on the body chamber and is not greater than that of the secondary ribs near the aperture. Concomitant with this, the point of division into secondary ribs shifts upward towards the middle of the whorl sides near the aperture. The primary ribs begin close to or at the umbilical suture line at the end of the body chamber of J 26447 (fig. 158b). The last two primary ribs of this specimen are approximated. The secondary ribs of J 26447 are interrupted along a narrow band along the siphonal line on the rear part of the body chamber and become uninterrupted and strong near the aperture. The two figured specimens J 24350 and J 26447 are probably mature and nearly complete.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24350	11	20.8	9.1	9	6.4	44	43	31	21 10	18 12
MNHB J 26447	10	18.6	7.8	7.5	5.2	42	40	28	20	17

Table 72. Dimensions of *Rasenioides paralepidulus* (Schneid).

Affinities: The two *Rasenioides paralepidulus* (Schneid) as figured here are somewhat smaller than the holotype that seems to be a complete adult. Schneid (1939:146) thought that the holotype was probably juvenile. The ornamentation of the Swiss specimens is very similar to that of the holotype. The whorl section near the aperture of the Swiss specimens corresponds to that as drawn by Schindewolf (1926, text-fig. 4 on p. 506). *Rasenioides striolaris* (Reinecke) has more and finer secondary ribs per primary to judge of the drawing in Reinecke (1818, pl. 6:52). *Rasenioides thermarum* (Oppel, 1863:243, pl. 65:5, see also photographic reproduction of the holotype in Geyer, 1961, pl. 8:9) has the same small size as *Rasenioides paralepidulus* (Schneid), but Oppel (1863:243) stated that his taxon has about 100 secondary ribs on the last whorl. This is almost twice the number of secondary ribs that can be counted on the last whorl of Swiss *Rasenioides paralepidulus. Rasenioides pseudolepidulus* (Geyer, 1961) has much more and finer ribs than *Rasenioides paralepidulus,* and it is larger.

Material: 2 specimens: MNHB J 24350, J 26447.



a b

Fig. 159. *Sutneria (Sutneria) platynota* (Reinecke).

a: *Sutneria (Sutneria) platynota* (Reinecke), morphotype A Schairer, MNHB J 32810.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 120: lowermost Baden Member; coll. R. Gygi.

b: *Sutneria (Sutneria) platynota* (Reinecke), morphotype C Schairer, MNHB J 23634.
Excavation RG 239, Summerhalde near Schaffhausen, bed no. 30: lower Schwarzbach Formation; coll. R. & S. Gygi. ×2.

Family Aspidoceratidae Zittel, 1895

Subfamily Physodoceratinae Schindewolf, 1925

Genus *Sutneria* Zittel, 1884

Subgenus *Sutneria* Zittel, 1884

Type species: Nautilus platynotus Reinecke, 1818.

Sutneria (Sutneria) platynota (Reinecke, 1818), morphotypes A and C Schairer, 1970
Fig. 159a–b

Remark: Sutneria (Sutneria) platynota (Reinecke) is one of the oldest ammonite taxa at all and is well-known. It was subdivided into the three temporally successive morphotypes ("Formengruppen") A–C by Schairer (1970). Two of these morphotypes (A and C) were recorded in the excavation RG 239 at Summerhalde, Schaffhausen, Switzerland (fig. 159b, see also fig. 160). The first figured and very well-preserved representative of morphotype A from Switzerland was described and figured by Gygi (2000a, pl. 13:2) who also gave a list of recent synonyms (p. 98). The specimen of morphotype A as figured here is deformed and not well-preserved. Nevertheless, it is important as a documentation of the presence of the Platynota Zone in Canton Aargau that was already recorded by Moesch (1867, table on p. 191).

Morphotype C (fig. 159b) was found to date in northern Switzerland only in excavation RG 239 at Summerhalde near Schaffhausen (fig. 160). The vertical range of the taxon is from bed no. 26 to 30 of the lowermost Schwarzbach Formation. This formation is the time equivalent of the Baden Member and of the lowermost part of the Wettingen Member in Canton Aargau (Gygi, 2000a, fig. 40).

Subfamily Aspidoceratinae Zittel, 1895

Genus *Aspidoceras* Zittel, 1868

Type species: Ammonites rogoznicensis Zeuschner, 1846.

Aspidoceras uninodosum Toula, 1907
Fig. 161a–b; table 73

1985 *Aspidoceras uninodosum* Toula – Checa Gonzalez, p. 70, text-fig. II.3.3D, II.3.4A–C, II.3.5A–B, II.3.8A–D, pl. 4:3, pl. 6:2, pl. 7:1–2, with synonymy.

Lectotype: Plate 13:1 in Toula, 1907, designated by Checa Gonzalez (1985:71).

Type locality: Giesshübl near Vienna, Austria.

Type horizon: Acanthicum Beds.

Description: The glauconitic, carbonate internal mould of MNHB J 26479 is septate to the diameter of 90 mm. Half of the last whorl is occupied by the body chamber. The whorl section is thick-oval and slightly depressed (table 73). The umbilical wall is vertical. There are seven low tubercles on the umbilical margin of the last half whorl. The tubercles are elongate and swing back like very short and weak ribs. The last whorl covers the preceding one by 50%.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 26479	90	111	46.5	-	33.9	42	-	30	–	–
MNHB J 26489	81	78	34.5	35.7	20.1	44	46	26	–	–

Table 73. Dimensions of *Aspidoceras uninodosum* Toula.

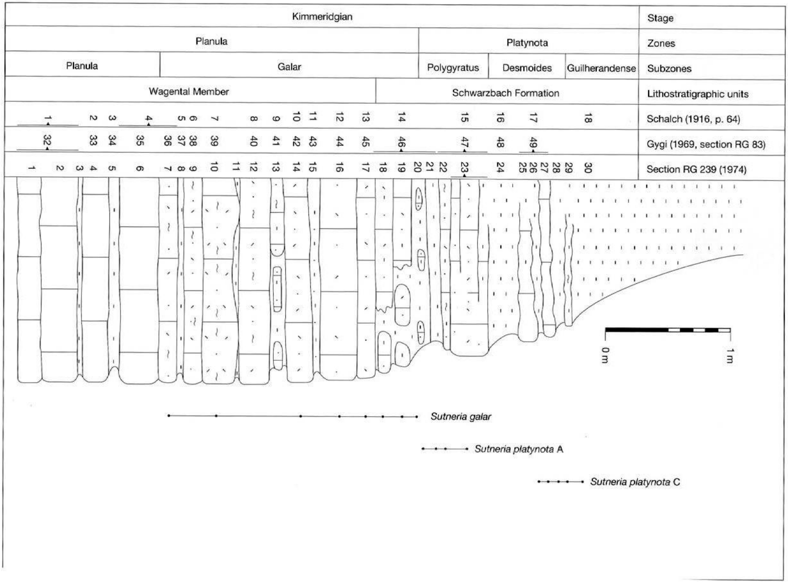


Fig. 160. Section of excavation RG 239 at Summerhalde near Schaffhausen.

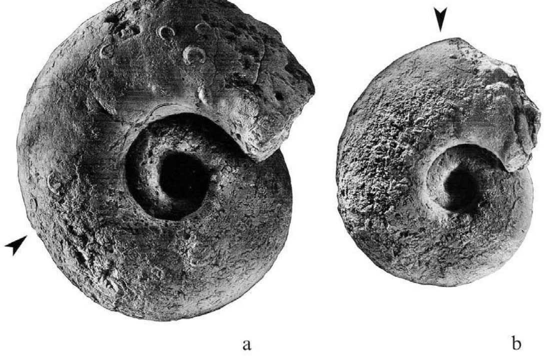


Fig. 161. *Aspidoceras uninodosum* Toula.
a: MNHB J 26479;
b: MNHB J 26489.
Both section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

Affinities: The configuration and the distance of the tubercles in MNHB J 26479 correspond well with what is visible of tubercles in the lectotype. The whorl section corresponds to that given by Toula (1907, text-fig. 24 on p. 59). Checa Gonzalez (1985:71) stated that there is a double row of tubercles on the innermost whorls until the "length" (= diameter?) of 45–50 mm at most. Nothing can be seen of an outer row of tubercles at the diameter of 40 mm in the smaller Swiss specimen J 26489 (fig. 161b). Checa Gonzalez (1985:74) found that the acme of the vertical range of *Aspidoceras uninodosum* Toula is in the Uhlandi Subzone of the Divisum Zone and in the lowermost part of his Compsum (= Acanthicum) Zone in the Subbetical Zone of Spain (see fig. II.3.9 on p. 73). The age of the forms figured here cannot be indicated exactly. It is probably late Hypselocyclum Chron. *Pseudhimalayites uhlandi* (Oppel) was found at Mellikon, Canton Aargau, only further above, in the lower Wettingen Member (see Gygi, 2000a, pl. 15:1), whereas the two *Aspidoceras uninodosum* Toula J 26479 and J 26489 were found in the glauconitic lower Baden Member.

Material: 2 specimens: MNHB J 26479, J 26489.

Aspidoceras binodum (Oppel, 1863)

Fig. 162; table 74

1985 *Aspidoceras binodum* (Oppel) – Checa Gonzalez, p. 54, pl. 1:1, pl. 2:2–5, pl. 3:1, with synonymy.

Holotype: Specimen described by Oppel (1863, p. 217), not figured.

Type locality: Nusplingen south of Balingen, Württemberg, southern Germany.

Type horizon: Unknown.

Description: The glauconitic, carbonate internal mould of MNHB J 24252 is septate to the diameter of 74 mm. Somewhat more than half of the last whorl is occupied by the body chamber. The whorl section is depressed with a whorl thick-

Fig. 162. *Aspidoceras binodum* (Oppel), MNHB J 24252.
Section RG 70, large quarry, Mellikon, Canton Aargau, bed no. 124: lower Baden Member.
Coll. R. & S. Gygi. ×1.

ness that is markedly greater than the whorl height (table 74). The section of the siphonal side is a half-circle corresponding to text-figure II.3.1C in Checa Gonzalez (1985). The umbilical wall is very steep, but not vertical. An inner row of nodes is above the umbilical margin. Above the before-last inner node on the body chamber is a short spine that is inclined inward towards the coiling axis (visible in fig. 162). The outer row of nodes is at somewhat less than half of the whorl height. Most of the outer nodes form a pair with the inner nodes, but sometimes there is an intercalated outer node. The node pairs are connected by a low ridge. There are 15 outer nodes on the last whorl of J 24252 as compared with eleven on the holotype (Oppel, 1863:218).

Affinities: MNHB J 24252 corresponds well to the description of the holotype by Oppel (1863:217) and to the figures by Checa Gonzalez (1985).

Material: 1 specimen: MNHB J 24252.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24252	74	96.8	45.3	52	26.9	47	54	28	-	-

Table 74. Dimensions of *Aspidoceras binodum* (Oppel).

3.2.3 Perisphinctaceans of the Wettingen Member

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphinctinae Steinmann, 1890

Genus *Lithacosphinctes* Olóriz, 1978

Type species: Ammonites lictor evolutus Quenstedt, 1887 [M].

Lithacosphinctes n.sp. [M]
Fig. 163–164; table 75

Description: The carbonate internal mould of MNHB J 24179 is septate to the diameter of 240 mm. Three quarters of the last whorl are occupied by the body chamber. The peristome is not preserved. The section of the body chamber is oval. The primary ribs of the inner whorls are low, but sharp-edged. They are straight and radial. The primary ribs become faint and blunt from the diameter of about 120 mm. No secondary ribs are visible at the beginning of the last whorl. They must fade away earlier in ontogeny than at the diameter of 210 mm. The siphonal side of the last whorl is smooth. The primary ribs become strong and blunt, simple ridges on the last half whorl. The height of the last two ridges diminishes towards the aperture. This is an indication that the body chamber is complete. The last whorl covers the preceding one by about 25%.

Affinities: Lithacosphinctes n.sp. MNHB J 24179 has no published counterparts in the Divisum Zone, but it closely resembles *Lithacosphinctes villae* n.sp. of the Bimammatum Zone (see above) in its size, dimensions and in the ornamentation. *Lithacosphinctes* n.sp. J 24179 was found by A. Villa, a machine operator in the quarry at Mellikon, Canton Aargau, and he told the author that the specimen came from the light, micritic and well-bedded limestones of the lower Wettingen Member above the Baden Member. It might be argued that this is not the case, and that J 24179 is rather from the lower Villigen Formation. But the matrix of J 24179 is a lighter beige than that of the lower Villigen Formation in the quarry RG 70 at Mellikon, and the ammonite has a dark-brown crust at the underside. Such a dark-brown crust does not occur on ammonites of the lower Villigen Formation in section RG 70 at Mellikon, but it was found on *Pseudhimalayites uhlandi* (Oppel) J 32927 from the lower Wettingen Member in the same section. It is therefore very probable that *Lithacosphinctes* n.sp. J 24179 is indeed from the lower Wettingen Member of section RG 70. In this case, it would be the youngest *Lithacosphinctes* that is known to date that differs only slightly by

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 24179	240	347	93	82	177	27	24	51	347 300 200 160 120 100	22 25 29 30 33 37

Table 75. Dimensions of *Lithacosphinctes* n.sp.

Fig. 163. *Lithacosphinctes* n.sp., MNHB J 24179.
Section RG 70, large quarry, Mellikon, Canton Aargau, from a bed in the lower part of the succession of beds no. 126–171 (total thickness: 9.8 m): lower Wettingen Member.
Coll. A. Villa. ×0.6.

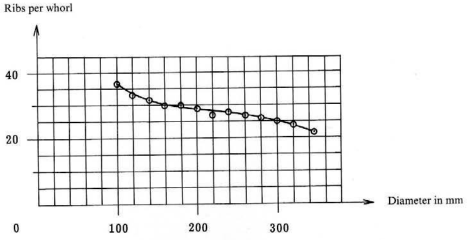


Fig. 164. Rib curve of *Lithacosphinctes* n.sp., NMHB J 24179.

the rib curve from *Lithacosphinctes villae* n.sp. of the lower Villigen Formation. *Lithacosphinctes* n.sp. is probably the successor of *Orthosphinctes (Lithacosphinctes) davidi* Atrops (1982, pl. 35:1) of the Lothari Subchron of the Hypselocyclum Chron.

Material: 1 specimen: MNHB J 24179.

Genus *Tolvericeras* Hantzpergue, 1987

Type species: Tolvericeras (Tolvericeras) tolverense Hantzpergue, 1987.

Tolvericeras (Tolvericeras) n.sp.

Fig. 165–166; table 76

1961 *Katroliceras (Katroliceras) atavum* (Schneid) – Geyer, p. 42, table 20, pl. 4:1, non 4:6.

Description: The carbonate internal mould of MNHB J 24174 is septate to the diameter of 83 mm. The last septa are very incompletely visible and it cannot be established whether they are approximated or not. The whole of the last whorl is occupied by the body chamber. The whorl section is oval with a vertical umbilical wall. The primary ribs are strong and blunt. They begin at the umbilical suture line and there swing back on the body chamber. Some of them are straight, but the majority of them is proconcave on the whorl sides. The forward inclination of the primary ribs is 5–10°. The point of division into secondary ribs is at 58% of the whorl height at the beginning of the body chamber. Then the point of division becomes blurred and shifts downward on the whorl sides. Most of the ribs on the body chamber are fascipartite and polygyrate. On the rear part of the body chamber, the secondary ribs bend somewhat more forward than the primaries and form a proconvex arc on the siphonal side. There are up to four secondary ribs per primary. The configuration and the distanc between the primary ribs does not change near the end of th body chamber. The last whorl covers the preceding one by 42% There is no egression (uncoiling) of the umbilical suture line.

Affinities: MNHB J 24174 is assigned to the genu *Tolvericeras*, not to *Progeronia*, because of its polygyrate rib bing. It cannot be established whether MNHB J 24174 is ma ture or not. Only the rib curve that descends from a culmina tion at the diameter of 80 mm (fig. 166) gives a hint that th specimen may be a small macroconch. In Oxfordia perisphinctids, such a variocostate rib curve indicates a macro conch in most cases (Gygi, 2001:10). But this is possibly in conclusive in perisphinctaceans of the Kimmeridgian whe *Parataxioceras* are taken into account.

Tolvericaeras (Tolvericeras) tolverense Hantzpergue with size comparable to that of J 24174 are less densely ribbed tha J 24174 (see Hantzpergue, 1989, pl. 10:a, d). Moreover, the are younger (Mutabilis Zone according to Hantzpergu 1989:156). On the other hand, J 24174 is very similar to *Katr liceras (Katroliceras) atavum* (Schneid) in Geyer (1961, p 4:1) from the upper part of Weisser Jura γ at Böhmenkirc southern Germany. The specimen as figured by Geyer is pro ably coeval with J 24174. Both specimens could be conspecif and belong to a new taxon within the subgenus *Tolvericeras.*

Material: 1 specimen: MNHB J 24174.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whc Dm	
MNHB J 24174	83	132	42.8	37.2	56.7	32	28	43	146 120 100 80 60	[illegible]

Table 76. Dimensions of *Tolvericeras (Tolvericeras)* n.sp.

Fig. 165. *Tolvericeras (Tolvericeras)* n.sp., MNHB J 24174.
Section RG 70, large quarry, Mellikon, Canton Aargau, to judge from the matrix: from the succession of beds no. 126–171: lower Wettingen Member. Coll. W. Bühler. ×1.

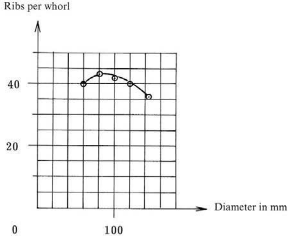


Fig. 166. Rib curve of *Tolvericeras (Tolvericeras)* n.sp., MNHB J 24174.

Family Simoceratidae Spath, 1924

Subfamily Idoceratinae Spath, 1924

Genus *Idoceras* Burckhardt, 1906

Type species: Ammonites balderus Oppel, 1863.

Idoceras balderum (Oppel, 1863)
Fig. 167

1959 *Idoceras balderum* (Oppel) – Ziegler, p. 25, text-fig. 1a, pl. 1:3–4, with synonymy.
1963 *Idoceras balderum* (Oppel) – Barthel, p. 30, pl. 4:4.
1978 *Idoceras balderum* (Oppel) – Olóriz, p. 134, pl. 11:1.
1980 *Idoceras balderum* (Oppel) – Barthel & Schairer, pl. 1:1, 3–4.
2000a *Idoceras balderum* (Oppel) – Gygi, p. 92, pl. 14:3.

Lectotype: Plate 67:2 in Oppel (1863), designated here.

Type locality: Baden, Canton Aargau, Switzerland.

Type horizon: Zone of *Ammonites tenuilobatus.*

Description: Most of the inner whorls are preserved as a mould (imprint). Part of the body chamber is an internal, carbonate mould. The body chamber probably begins at the diameter of about 50 mm. The last third of whorl of the body chamber is broken off, and only a partial imprint of it remains. The last ribs on this imprint are approximated and indicate that the complete shell had a diameter of about 98 mm.

Material: 1 specimen: MNHB J 28154.

Fig. 167. *Idoceras balderum* (Oppel), MNHB J 28154.
Section RG 70, large quarry, Mellikon, Canton Aargau, to judge from the matrix: from the succession of beds no. 126–171: lower Wettingen Member. ×1.

Family Ataxioceratidae Buckman, 1921

Subfamily Ataxioceratinae Buckman, 1921

Genus *Garnierisphinctes* Enay, 1959 [m]

Type species: Ammonites garnieri Fontannes in Dumortier & Fontannes, 1876.

Garnierisphinctes romanoi n.sp. [m]
Fig. 168–169; table 77

Holotype: MNHB J 32821, figure 166.

Type locality: Section RG 70, large quarry, Mellikon, Canton Aargau.

Type horizon: Succession of beds no. 126–171, lower Wettingen Member.

Derivation of the name: The name refers to Mr. Enrico Romano, mason, formerly at Füllinsdorf, Canton Basel-Landschaft, who sold a large collection of well-preserved and expertly prepared fossils, mainly from the Jura Mountains, to the Museum of Natural History, Basel.

Diagnosis: Representative of the genus *Garnierisphinctes* with a phragmocone that has the diameter of 83 mm. The taxon grows to the diameter of 132 mm. The ribbing is dichotome, and the secondary ribs form a proconvex arc on the siphonal side. The rib curve rises steadily to end. The peristome has short and broad lappets.

Description: The carbonate internal mould of MNHB J 32821 is septate to the diameter of 83 mm. Three quarters of the last whorl are occupied by the body chamber. This is complete with the peristome that has a short and broad lappet on the left side (reverse of the side shown in fig. 168). The whorl section is oval and very compressed. This is probably the effect of compaction. The primary ribs are strong and blunt. They begin at the umbilical suture line and swing back on the rounded umbilical wall. Some of them are straight on the whorl sides and some are slightly proconcave. The primary ribs are as a rule radial, but some of them lean a little forward and some a little backward. They split high on the whorl sides on the phragmocone. On the body chamber, the point of division can be as low as 57% of the whorl height. There are two secondary ribs per primary, but in one case on the body chamber, a primary rib is tripartite. The secondary ribs bend forward and form a proconvex arc on the siphonal side. The last whorl covers the preceding one by 37%.

Individual labelling of specimen	Ph mm	Dimensions, mm Dm	Wh	Wt	Um	in % of Dm Wh	Wt	Um	Ur/whorl Dm	n
MNHB J 32821	83	132	39.4	22.7	61	30	17	46	132	58
									100	56
									80	54
									60	50
									40	44
									20	38

Table 77. Dimensions of *Garnierisphinctes romanoi* n.sp.

Fig. 168. *Garnierisphinctes romanoi* n.sp., MNHB J 32821.
Section RG 70, large quarry, Mellikon, Canton Aargau, to judge from the matrix: from the succession of beds no. 126–171: lower Wettingen Member. Coll. E. Romano. ×1.

Affinities: The holotype MNHB J 32821 has almost exactly the same size and dimensions as the holotype of the type species of the genus, *Garnierisphinctes garnieri* (Fontannes), which is also complete with lappets. The main difference between the two taxa is in the ribbing of the last whorl. The ribbing on the last whorl of *Garnierisphinctes garnieri* (Fontannes) is irregular, whereas it is regularly dichotome (with the exception of a single tripartite rib) in the holotype of *Garnierisphinctes romanoi* n.sp.

Material: 1 specimen: MNHB J 32821.

Differential diagnosis: Garnierisphinctes romanoi n.sp. differs from *Garnierisphinctes garnieri* (Fontannes) in its regularly dichotome ribbing on the last whorl. The ribbing on the last whorl of *Garnierisphinctes garnieri* is irregular at the corresponding growth stage.

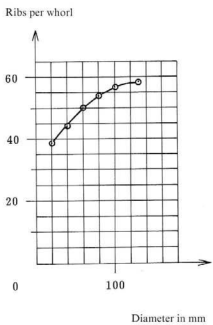


Fig. 169. Rib curve of *Garnierisphinctes romanoi* n.sp., MNHB J 32821, holotype.

4. Biostratigraphy

The division of the formations and members of the Upper Jurassic in northern Switzerland into biozones and subzones is represented in figures 170 and 174, where the vertical ranges of the perisphinctaceans described in this study are indicated.

4.1 Bimammatum Zone

The Bimammatum Zone was introduced by Oppel (1863:175). The index is *Epipeltoceras bimammatum* (Quenstedt). An incomplete representative of this taxon was figured by Gygi (2000a, pl. 10:4) from section RG 76, bed no. 11 of the Hornbuck Member below Hornbuck near Riedern am Sand, a fraction of Erzingen, southern Germany. Section RG 76 with the position of the specimen J 32268 as figured by Gygi (2000a, pl. 10:4) was depicted by Gygi (1969a, fig. 2 on p. 53).

4.1.1 Hypselum Subzone

The Hypselum Subzone was introduced by Dorn (1930:115). The index is *Euaspidoceras (Euaspidoceras) hypselum* (Oppel). A nearly complete adult of this taxon, J 27259, was figured by Gygi (2000a, pl. 10:1) from the upper part of the Effingen Member in the Wildegg Formation. The specimen was found by D. Krüger in a block fallen from the limestone succession of beds no. 55–80 in section RG 37 as figured by Gygi (1969a, pl. 17). The Hypselum Subzone probably extends into the lowermost Crenularis Member. This is indicated by the *Epipeltoceras* cf. *bimammatum* (Quenstedt) J 31726 as figured by Gygi (2000a, pl. 10:5). This specimen, J 31726, is transitional between *Epipeltoceras berrense* (Favre) of the uppermost Hypselum Subzone and *Epipeltoceras bimammatum* (Quenstedt) of the Bimammatum Subzone (Gygi, 2000a:101).

4.1.2 Bimammatum Subzone

The Bimammatum Subzone was characterized by Mouterde et al. (1971:96). The index is the same as for the zone. In section RG 70 at Mellikon, Canton Aargau, as figured in Gygi (1969a, pl. 17), the subzone is represented by numerous *Lithacosphinctes* and several *Ringsteadia* (fig. 170 of this study).

4.1.3 Hauffianum Subzone

The Hauffianum Subzone was introduced by Oppel (1863:175). The index is *Taramelliceras (Taramelliceras) hauffianum* (Oppel). There is no record of this taxon in northern Switzerland. It is concluded that the Wangen and the Küssaburg Member of the Villigen Formation represent the Hauffianum Subzone (see Gygi, 2000a, fig. 39), because *Epipeltoceras bimammatum* (Quenstedt) is restricted to the Hornbuck Member below, and *Subnebrodites planula* (Quenstedt) first appears in the lower Wangental Member above. It is probable that *Wegelea gredingensis* (Wegele) J 31720 as figured by Gygi (2000a, pl. 13:1) is a representative of the subzone.

4.2 Planula Zone

According to Atrops (1982:322) the Planula Zone was introduced by Engel (1908:404). But it was only widely used since Wegele (1929a:145). The index is *Subnebrodites planula* (Quenstedt). A representative of this taxon was figured by Gygi (2000a, pl. 11:5) from the lower Wangental Member at Hemmenthal, Canton Schaffhausen (section RG 84 that is schematically drawn in Gygi (1969a, pl. 19). The Planula Zone encompasses the Letzi Member of Canton Aargau and the Wangental Member of Canton Schaffhausen.

4.2.1 Planula Subzone

A Planula Horizon was first recognized by Zeiss (1965). Atrops (1982:322) discerned a Planula Subzone. The index is the same as for the Zone. The earliest representatives of *Subnebrodites* were found by Gygi (1969a) in the lowermost Wangental Member at Siblingen, Canton Schaffhausen (Gygi, 1969a, pl. 16, section RG 82, bed no. 134). One of these, *Subnebrodites schroederi* (Wegele), was figured by Gygi (2000a, pl. 13:4). The youngest representative of *Subnebrodites, Subnebrodites laxevolutus* (Fontannes), was found by Gygi (1969a, pl. 17) in the upper Letzi Member, bed no. 108 of section RG 70 at Mellikon, Canton Aargau. This specimen was figured by Gygi (2000a, pl. 11:4). Further ammonites that the author found in the Planula Subzone are indicated in sections RG 77, 78, 82 and 83 by Gygi (1969a, pl. 16).

4.2.2 Galar Subzone

According to Atrops (1982:322), the term Galar Zone was introduced by Veit (1936:135–136). Since Geyer (1961:143), the unit is regarded as the upper subzone of the Planula Zone. The index is *Sutneria (Sutneria) galar galar* (Oppel). A well-preserved representative of this taxon was figured by Gygi (2000a, pl. 13:3) that was found in bed no. 18 of excavation RG 239 at Summerhalde near Schaffhausen. The Galar Subzone is equivalent to the total vertical range of the index. The vertical range of the subzonal index in excavation RG 239 at Schaffhausen was indicated in a drawing of the section by Gygi (1990a:69) that is refigured here as figure 160. The youngest *Subnebrodites* were found in bed no. 4 of excavation RG 239, whereas the oldest *Sutneria galar* were found in bed no. 7 of this excavation.

4.3 Platynota Zone

According to Atrops (1982:323), the Platynota Zone was defined by Huguenin (1874) at Mt. Crussol near Valence in southeastern France. The index is *Sutneria (Sutneria) platynota* (Reinecke). A complete specimen belonging to morphotype A of this taxon was figured by Gygi (2000a, pl. 13:2). It is from bed no. 22 of excavation RG 239 of Summerhalde at Schaffhausen (fig. 160). In section RG 239, *Sutneria (Sutneria) platynota* A first appears in the upper part of bed no. 20, and morphotype C disappears in the lower part of bed no. 30.

4.3.1 Polygyratus Subzone

A succession with "*Perisphinctes (Orthosphinctes) polygyratus* (Reinecke)" was discerned by Schairer (1974:98) in the lower Platynota Zone. Atrops (1982:323) subdivided the Platynota Zone into three subzones and named the lowest subzone sous-zone à "*Orthosphinctes*". Atrops (1994:768) renamed the subzone sous-zone à Polygyratus that is adopted here. The index is *Orthosphinctes (Orthosphinctes) polygyratus* (Reinecke) *sensu* Geyer (1961:21). The Polygyratus Subzone begins with the upper part of bed no. 20 in section RG 239 of Summerhalde near Schaffhausen (fig. 160). The subzone approximately coincides with the vertical range of *Sutneria (Sutneria) platynota* (Reinecke), morphotype A Schairer 1970, as indicated by Gygi (1990a:69).

4.3.2 Desmoides Subzone

Sapunov (1977:67) introduced a Desmoides Zone that is equivalent to the entire Platynota Zone. Atrops (1982:324) discerned a Desmoides Subzone in the middle of the Platynota Zone that is adopted here. The index is *Orthosphinctes (Ardescia) desmoides desmoides* (Wegele). *Sutneria (Sutneria) platynota* (Reinecke), morphotype C Schairer 1970, first appears in the upper part of this subzone (fig. 160).

4.3.3 Guilherandense Subzone

Atrops (1982:325) introduced the Guilherandense Subzone as the uppermost subzone of the Platynota Zone. The index is *Ataxioceras (Schneidia) guilherandense* Atrops. The vertical range of *Sutneria (Sutneria) platynota* (Reinecke), morphotype C Schairer 1970 (fig. 159b), extends into this subzone as is indicated in figure 160.

4.4 Hypselocyclum Zone

The Hypselocyclum Zone was proposed by Geyer (1961:143) and was revised by Atrops (1982:327). The index is *Ataxioceras (Ataxioceras) hypselocyclum* Fontannes. The zone is well represented by several taxa of *Ataxioceras* in bed no. 124 of section RG 70 at Mellikon, Canton Aargau. The top of the zone as conceived by Atrops (1982) probably coincides approximately with the top of bed no. 124 of section RG 70.

4.4.1 Hippolytense Subzone

Atrops (1982:327) subdivided the Hypselocyclum Zone into two subzones: the Hippolytense Subzone below and the Lothari Subzone above. The index of the Hippolytense Subzone is *Ataxioceras (Parataxioceras) hippolytense* Atrops. The subzone begins above the last appearence of *Sutneria platynota* C. In the lower part of the subzone occurs *Ataxioceras (Schneidia) lussasense* Atrops (see this study, fig. 125 and 170). According to Atrops (1982:327), *Ataxioceras (Parataxioceras) pseudoeffrenatum* Wegele is represented in the upper part of the subzone (see this study, fig. 114 and 170).

4.4.2 Lothari Subzone

The Lothari Subzone was proposed by Atrops (1982:327). The index is *Ataxioceras (Parataxioceras) lothari lothari* (Oppel). This subzone is represented in the upper part of bed no. 124 of section RG 70 at Mellikon, Canton Aargau, by *Ataxioceras (Parataxioceras) evolutum* Atrops (fig. 122, 153), *Ataxioceras (Parataxioceras) oppeli oppeli* Geyer (fig. 116) and *Balticeras pommerania* Dohm (fig. 153–156). *Crussoliceras sayni* (Camus & Thieuloy) (fig. 133) and *Crussoliceras tenuicostatum* (Geyer) (fig. 135) occur in the uppermost part of the subzone.
The vertical ranges of the ammonites of the Hypselocyclum Zone as indicated in figure 170 are read from Atrops (1982) as far as possible. The vertical ranges of further ammonites of this zone that are indicated in figure 170 are conjectural.

4.5 Divisum Zone

The Divisum Zone was named by Geyer (1961:143). The index is *Crussoliceras divisum* (Quenstedt). In the opinion of Geyer (1961, table 24) the taxon is represented at Baden, Canton Aargau (see de Loriol 1877:54 and pl. 5:7). *Crussoliceras divisum* (Quenstedt) could be found neither in section RG 47 at Baden (Gygi, 1969a, pl. 17) nor in section RG 70 near Mellikon, Canton Aargau. According to several authors, it is probable that *Crussoliceras divisum* (Quenstedt) occurs in the lower part of the zone.

4.5.1 Divisum Subzone

The Divisum Subzone is thought to be represented at Mellikon by a marl with a thickness of somewhat more than one meter. This is bed no. 125 of section RG 70. Only a few siliceous sponges, but no ammonites were found in this bed. Hantzpergue et al. (1997:91) proposed a Divisum Subzone for the Submediterranean faunal province. This is at variance with their table 12 on page 88 where they proposed a Tenuicostatum Subzone for the same time interval in this province. The Divisum Subzone is preferred here, because *Crussoliceras tenuicostatum* (Geyer) was found in bed no. 124 of section RG 70 in the large quarry of Mellikon, Canton Aargau (fig. 135). This bed is the glauconitic, marly limestone of the lower Baden Member. Therefore, it cannot be excluded that *Crussoliceras tenuicostatum* (Geyer) first appears in the upper

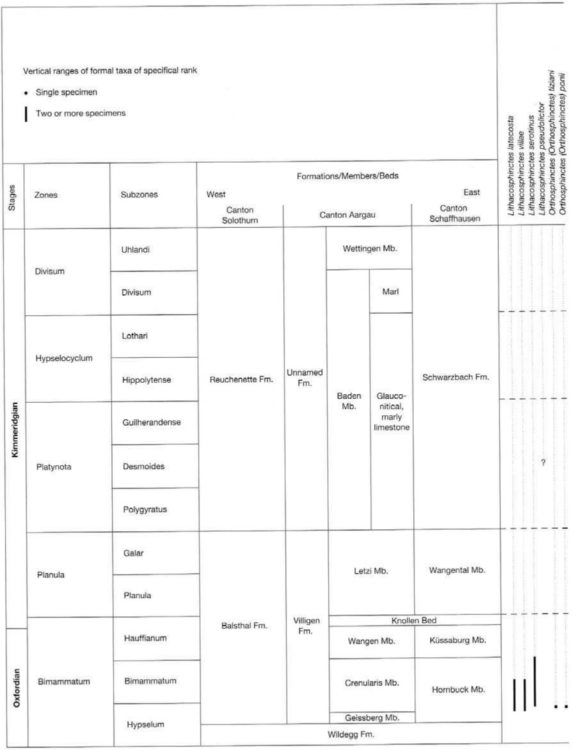
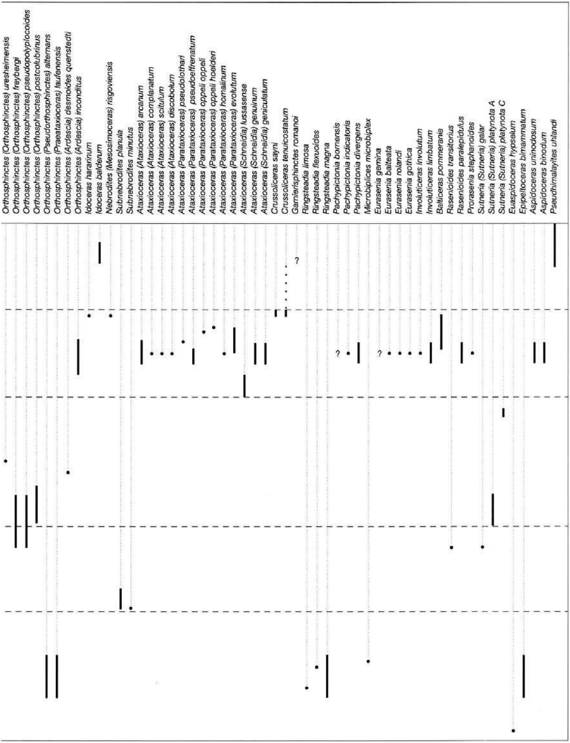


Fig. 170. Vertical ranges of formal perisphinctacean taxa of specific rank figured in this study. Zones and subzones are mainly after Cariou et al. (1991) and Hantzpergue et al. (1991).

Euaspidoceras hypselum, *Epipeltoceras bimammatum* and *Pseudhimalayites uhlandi* are figured in Gygi (2000a). No ammonites were found in the marl of the upper Baden Member that is assumed to represent the Divisum Subzone. The dashed line referring to *Crussoliceras tenuicostatum* (Geyer) represents the vertical range of this taxon in France (see text).


Orthosphinctes (Orthosphinctes) uresheimensis
Orthosphinctes (Orthosphinctes) freybergi
Orthosphinctes (Orthosphinctes) pseudopolyplocoides
Orthosphinctes (Orthosphinctes) postcolubrinus
Orthosphinctes (Pseudorthosphinctes) alternans
Orthosphinctes (Praeataxioceras) laufenensis
Orthosphinctes (Ardescia) desmoides quenstedti
Orthosphinctes (Ardescia) inconditus
Idoceras hararinum
Idoceras balderum
Nebrodites (Mesosimoceras) risgoviensis
Subnebrodites planula
Subnebrodites minutus
Ataxioceras (Ataxioceras) arcanum
Ataxioceras (Ataxioceras) complanatum
Ataxioceras (Ataxioceras) scitulum
Ataxioceras (Ataxioceras) discobolum
Ataxioceras (Parataxioceras) pseudolothari
Ataxioceras (Parataxioceras) pseudoeffrenatum
Ataxioceras (Parataxioceras) oppeli oppeli
Ataxioceras (Parataxioceras) oppeli hoelderi
Ataxioceras (Parataxioceras) homalinum
Ataxioceras (Parataxioceras) evolutum
Ataxioceras (Schneidia) lussasense
Ataxioceras (Schneidia) genuinum
Ataxioceras (Schneidia) geniculatum
Crussoliceras sayni
Crussoliceras tenuicostatum
Garnierisphinctes romanoi
Ringsteadia limosa
Ringsteadia flexuoides
Ringsteadia magna
Pachypictonia bornensis
Pachypictonia indicatoria
Pachypictonia divergens
Microbiplices microbiplex
Eurasenia gemina
Eurasenia balteata
Eurasenia rolandi
Eurasenia gothica
Involuticeras involutum
Involuticeras limbatum
Balticeras pommerania
Rasenioides transitorius
Rasenioides paralepidulus
Prorasenia stephanoides
Sutneria (Sutneria) galar
Sutneria (Sutneria) platynota A
Sutneria (Sutneria) platynota C
Euaspidoceras hypselum
Epipeltoceras bimammatum
Aspidoceras uninodosum
Aspidoceras binodum
Pseudhimalayites uhlandi
?
?
?

Lothari Subzone of the Hypselocyclum Zone. Nevertheless, presence of the taxon *tenuicostatum* near Mellikon (fig. 135) can be taken as evidence that the Divisum Subzone is represented in northern Switzerland (fig. 170).

4.5.2 Uhlandi Subzone

According to Karvé-Corvinus (1966:129), an Uhlandi Zone was first discerned by Veit (1936). Mouterde et al. (1971:98) hinted that this zone had already been introduced by Grünvogel (1914). Hantzpergue et al. (1997:91) confirmed this and proposed an Uhlandi Subzone. The index is *Pseudhimalayites uhlandi* (Oppel). Several representatives of this taxon were found in the large quarry at Mellikon (section RG 70) in the lower Wettingen Member. One of them was figured by Gygi (2000a, pl. 15:1). This specimen, J 22901, was collected before section RG 70 was measured. Its provenance from the lower Wettingen Member can only be concluded from the matrix. In 1962, after measuring section RG 70, the author found *Pseudhimalayites uhlandi* (Oppel), J 32927, at the upper surface of bed no. 126 in section RG 70. *Idoceras balderum* (Oppel) Gy 1611 was collected at the same time from the top of bed no. 128 of section RG 70 (Gygi, 1969a, pl. 17). Another *Idoceras balderum* (Oppel), J 31719, was found by the author at the top of bed no. 124 of section RG 62 east of Schrannechopf near Villigen, Canton Aargau (Gygi, 1969a, pl. 17). This specimen was figured by Gygi (2000a, pl. 14:3). The vertical ranges of *Pseudhimalayites uhlandi* (Oppel) and *Idoceras balderum* (Oppel) seem to be the same in Canton Aargau. According to Atrops (1982:330), this is also the case in southeastern France. Karvé-Corvinus (1966:130) envisaged a Balderum Zone above her Uhlandi Zone at Mt. Crussol near Valence, southeastern France.

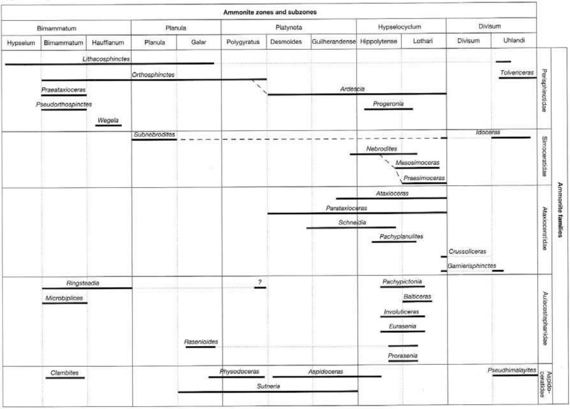


Fig. 171. Vertical ranges and phylogenetic links between the studied perisphinctacean genera and subgenera.

5. Phylogeny: Some remarks

The perisphinctaceans described in this study were found mainly in section RG 70 in the large quarry near Mellikon, Canton Aargau. In this quarry, ammonites are fairly abundant in the lower Villigen Formation that Gygi (1969a, pl. 17) called Crenularis Member of the Bimammatum Subzone, and they are abundant in the glauconitic lower Baden Member. The thickness of the lower Baden Member is at Mellikon only 1.1 m, but this unit encompasses the whole Platynota and the Hypselocyclum Zone. Few ammonites could be collected from this bed from *in situ* by hand. Most specimens were found when a heavy bulldozer removed the bed that is overburden for the quarrymen. These ammonites are a grab sample. Their chronological position in the range chart of figure 170 and in figure 171 had therefore to be read from Atrops (1982) and from other sources. The names in figure 171 are generic and subgeneric. They belong to macroconchs as well as to microconchs.

Family Perisphinctidae: *Lithacosphinctes* [M] and *Orthosphinctes* [m] are conservative forms. *Lithacosphinctes* probably evolved from *Ampthillia,* and *Orthosphinctes* from *Dichotomoceras* of the Bifurcatus Chron. *Wegelea* closely resembles *Larcheria* from the Schilli Zone of the Oxfordian.

Family Simoceratidae: *Subnebrodites, Idoceras* and *Nebrodites* are thought to be derived from *Passendorferia.*

Family Ataxioceratidae: The ancestral genus from which *Ataxioceras, Parataxioceras* and *Schneidia* evolved is possibly *Eoataxioceras* of the Transversarium Chron (Gygi, 2001:161). This is uncertain because of the wide temporal gap between *Eoataxioceras* and *Ataxioceras. Praeataxioceras* Atrops (1982:50) is closely related to *Orthosphinctes.*

Family Aulacostephanidae: No details are known of the descent of this family from the main stock of Perisphinctidae (see Donovan et al., 1981, fig. 5). *Ringsteadia* of the Late Oxfordian, the oldest genus of Aulacostephanidae, is morphologically quite distant from coeval Perisphinctidae. There are no species of *Ringsteadia* that occur both in northwestern Europe, where the genus was introduced, and in central Europe. Arkell in Arkell et al. (1957:324) thought that *Balticeras* is a subgenus of *Ringsteadia,* and that it occurred in the Upper Oxfordian. The numerous *Balticeras* that were later found in northern Switzerland are evidence that mature specimens of this genus are giant like *Ringsteadia magna* n.sp. from the Bimammatum Subzone. But *Balticeras* is much younger than indubitable *Ringsteadia.* The *Ataxioceras (Parataxioceras) evolutum* Atrops J 32834 adhering to *Balticeras pommerania* Dohm J 24181 (fig. 153) indicates that *Balticeras pommerania* Dohm is a taxon of the Lothari Subzone of the Hypselocyclum Zone. The main difference between *Ringsteadia* and *Balticeras* is that in age. But there are also morphological differences: *Balticeras* has never a sphenoidal whorl section as it is found at a diameter of 350 mm in *Ringsteadia magna* n.sp. J 32644, holotype, or at the diameter of 250 mm in the paratype J 30508. Unlike *Ringsteadia* with an inclined umbilical wall (see for instance fig. 26), inner whorls of *Balticeras* have a vertical umbilical wall. In this they resemble inner whorls of *Pachypictonia divergens.* It has been noted above that in some cases it is difficult to distinguish *Pachypictonia* from *Involuticeras. Pachypictonia, Balticeras* and *Involuticeras* are probably closely related.

Family Aspidoceratidae: It is likely that *Clambites* of the Bimammatum Subzone is the direct descendant of *Euaspidoceras* from the Hypselum Subzone of the Bimammatum Zone. The microconch *Epipeltoceras* may be derived from *Mirosphinctes* that Bonnot in Bonnot & Gygi (2001) links as microconchs to macroconch *Euaspidoceras.* Keupp (2000:81) assigned the microconch *Sutneria platynota* (Reinecke) to macroconch *Physodoceras circumspinosum* (Quenstedt). It is interesting to note that the last *Sutneria galar* (Oppel) and the earliest *Sutneria platynota* (Reinecke), morphotype A Schairer, were both found in bed no. 20 of excavation RG 239 at Summerhalde near Schaffhausen (fig. 160). This does not necessarily mean that the vertical ranges of the two taxa overlap within this bed. No intermediate stages between the two taxa occur in bed no. 20 of excavation RG 239. The sedimentation rate of bed no. 20 was slow, but there is no evidence of condensation.

6. Palaeogeography

According to Ziegler (1988, pl. 13), the area of what is now northern Switzerland was in Late Jurassic time an epicontinental sea. Land was in the north (London-Brabant Massif, Rhenish Massif), and the oceanic Tethys was in the state of spreading in the south. The oldest palaeogeographic map of the Oxfordian in northern Switzerland was drawn by Gressly (1838–1841, pl. 6). Gressly may be the inventor of this type of map. He distinguished on the map a "région littorale avec bancs à coraux" in northwestern Switzerland from a "région des faciès à polypiers spongieux" near Olten and Aarau. It is evident from Gressly's plate 10:8, that his coral banks near Huggerwald (a fraction of the village Kleinlützel, Canton Solothurn) are those of what is now called St-Ursanne Formation of the Middle Oxfordian (Gygi, 2000a, fig. 39). On page 13 Gressly called this "facies corallien" and stated that oolite belongs to this facies. On page 17 he noted that ammonites occur in fine-grained rocks. On page 19 he assigned the "polypiers spongieux" to a subpelagical environment and noted on page 20 that with the appearance of sponges, the fossils from littoral facies disappear. He added that ammonites and belemnites are abundant in the sponge facies. Only what is now the Birmenstorf Member in the lower Wildegg Formation can be meant by the sponge facies of Gressly. The representation of the "facies corallien" side by side with the sponge facies on Gressly's map does not mean that Gressly regarded the two facies to be time-equivalent (see below). But the time correlation of the St-Ursanne Formation in Canton Jura with the Birmenstorf Member in Canton Aargau is now well established by perisphinctid ammonites that Pümpin (1965) found in the upper St-Ursanne Formation near St-Ursanne. These were figured by Gygi (1995, fig. 4 and 14). The same taxa occur also in the Birmenstorf Member of Canton Aargau (Gygi, 2001, fig. 168) and in the coeval Mumienkalk Bed of Canton Schaffhausen (Gygi, 2001, fig. 86). Gressly's conclusion that hermatypic corals grew in shallow water and that ammonites were abundant in deeper water was then correct. This was fundamental insight. It was since confirmed by different, ind pendent lines of evidence from sediments of Late Jurassic a in northern Switzerland that are summarized in Gygi (2000a Gressly introduced the term facies into the geologic literatu The pattern of vertical and lateral facies changes in the sec ments of the Late Jurassic of northern Switzerland is therefo of general interest to sedimentary geology and deserved to investigated in detail. A succession of palaeogeographic ma of the main facies types in the Late Jurassic of northe Switzerland that are based on detailed correlations by ar monite biostratigraphy and clay mineral stratigraphy by Gy & Persoz (1986) was published by Gygi (1990c).

The palaeolatitude of northern Switzerland in Late Jurass time was, according to Firstbrook et al. (1979), about 3 north. The northern boundary of the coral-oolite facies at th time was, to judge from Arkell (1933, p. 422 and fig. 75 p. 426), north of Yorkshire in England, well north of 4 palaeolatitude. The northernmost coral reefs growing now the Atlantic ocean are those of Bermuda at 32° latitude. Co sequently, the belt of warm, tropical and subtropical clima was wider in the Late Jurassic than it is in Recent time.

This is confirmed by the fact that glendonites were nev found to date in marine sediments from high, Arctic palae latitudes of Late Oxfordian or Kimmeridgian age (Kemper Schmitz, 1981:769). Glendonites are aggregates of la crystals mainly of calcite. Kemper & Schmitz (1981) co cluded that the crystals are pseudomorphs after Thenard (Na_2SO_4), a mineral with a high degree of solubility that stable only in cold seawater. Recent glendonites occur in m rine claystones of the Arctic. In ancient rocks, they therefo indicate a cold, polar climate. Glendonites of Cretaceous a were figured by Kemper & Schmitz (1981, pl. 1) from the u per Deer Bay Formation (Valanginian) in the Sverdrup Ba in the Canadian Arctic.

7. Palaeoclimate

The coral bioherms that occur in the St-Ursanne, the Günsberg, the Balsthal and in the lower Reuchenette Formation (fig. 173), the accretion bands that are visible in some coral colonies (fig. 172), and the palaeolatitude of between 30° and 35° according to Firstbrook et al. (1979) in Gygi (1981:243), are evidence that the climate was subtropical in northern Switzerland in Late Jurassic time. The climate varied between humid and substantially drier times. This is indicated by the almost ubiquitous presence of the clay mineral kaolinite in the rocks analyzed by Persoz in Gygi & Persoz (1986). According to Persoz in Gygi & Persoz (1987:59), most of this kaolinite is inherited and is consequently indicative of the relatively humid climate on land of the London-Brabant Massif and the Rhenish Massif, where kaolinite was formed by weathering of rocks. According to Griffin (1962), kaolinite is formed in warm climates with adequate rainfall. A humid climate is confirmed by the occurrence of characean gyrogonites and limnic ostracods in terrestrial facies in the Röschenz Member that were reported by Ziegler (1962). Allenbach in Allenbach & van Konijnenburg-van Cittert (1997) found land plants in the coeval Günsberg Formation near Court, Canton Bern. Gygi (2000a) found no evaporites in marginal marine facies of the Röschenz Member in the Vellerat Formation and in the Günsberg Formation. But he confirmed the existence of a thin coal seam above a calcrete, indicative of a supratidal swamp in the upper Günsberg Formation in the gorge north of Moutier.

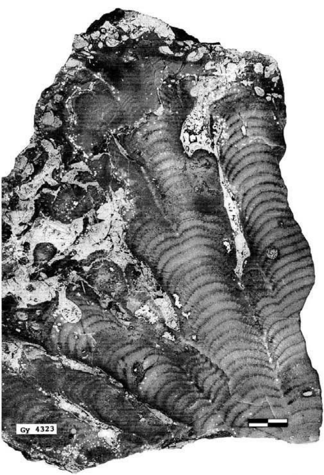


Fig. 172. Cross-cut, thickly-branching colony of the hermatypic coral *Cryptocoenia limbata* Goldfuss with accretion bands that probably correspond to yearly growth.
Polished slab Gy 4323 from a bioherm in the uppermost St-Ursanne Formation beside the road from Courtételle, Canton Jura, to the farm Les Fouchies, unpublished section RG 370, bed no. 11. Bar is 2 cm.

Canton Bern (Gygi, 2000a:38, pl. 27, section RG 390, top of bed no. 80; cf. Kemmerling, 1911:22).

The rate of supply of argillaceous mud from land in the north to the epicontinental basin in northern Switzerland varied greatly with time. It was minimal at the beginning of the Late Jurassic, then increased and was at a maximum just before the end of deposition of the argillaceous Bärschwil Formation (Gygi, 1999, fig. 1). The high rate of supply of argillaceous mud is interpreted to be indicative of a relatively wet climate when much rock was weathered on land. Then the supply of argillaceous mud suddenly dropped to a minimum when the carbonate platform of the St-Ursanne Formation accumulated. This limestone formation is probably evidence of a drier climate and of a greatly reduced rate of siliciclastic sediment supply from land. However, vegetation on land survived. Pümpin (1965, fig. 21) found a leaf of a cycadean land plant in the lagoonal Buix Member of the upper St-Ursanne Formation in the quarry near the railway station of St-Ursanne (see Gygi, 2000a, fig. 39). A relatively wet climate certainly prevailed when the great amount of argillaceous mud of the Effingen Member was laid down. This is evident from the coal seams, limnic ostracods and characean gyrogonites and from the absence of evaporites in the coeval, marginal marine and partly terrestrial Röschenz Member of the Vellerat Formation and of the Günsberg Formation. The Balsthal Formation above is again a purely carbonate platform sediment. Coral bioherms found in the oolitic Verena Member even in the platform interior (fig. 173) indicate a normal salinity and good circulation of the very shallow water. On the other hand, dolomite (Gygi, 2000a, fig. 16), pseudomorphs of calcite after sulfate replacing carbonate ooids (Gygi, 2000a, fig. 26) and even a thin and local deposit of impure gypsum (Gygi, 2000a:45, pl. 35, section RG 400, bed no. 113, thin section Gy 7706) occur in the Verena Member. Consequently, the Balsthal Formation was sedimented during a relatively dry climate.

No land plants were found so far in the Reuchenette Formation. Nevertheless, vegetation on land must have been plentiful enough during deposition of the Reuchenette Formation that large plant-eating dinosaurs could make a living. Evidence of this are dinosaur footprints on ancient tidal flats. Such a tidal flat with shallow, but very distinct, circular footprints with a diameter of 0.5 and 0.7 m, respectively, was found by the author in the eastern quarry of Steingrueben on the territory of the township Oberdorf, Canton Solothurn, in July 1986 when he measured section RG 434. The footprints were recorded on the upper surface of bed no. 17 of the section. The bed was quarried as a building stone at that time. It includes very abundant nerineid gastropods (polished slab Gy 5039) and some terebratulid brachiopods. Nerineids are indicators of a very shallow marine environment (Gygi, 2000a:49 and pl. 42). A sausage-like bulge encircled the margin of the footprints. The diameter of the "sausages" was between 6 and 8 cm. The footprints were shallow with a flat bottom, in spite of the great weight of the animals that produced them and the giant size of the dinosaurs that must be concluded from the diameter of the footprints. This indicates that the tidal flat the dinosaurs walked on was firm. Only the uppermost few centimeters of the sediment were soft and could be squeezed into the sausage-like rings around the footprints by the tread of the animals.

Soon after the section was measured, bed no. 17 and bed no. 16 below were removed by a large-scale blasting. The upper bedding plane of bed no. 15 was thereby uncovered on a va
surface, and C. Meyer found more footprints in February 19
that are now visible on the surface (Meyer, 1990:391). Anoth
ancient tidal flat with shallow, very well-preserved dinosa
footprints in the Reuchenette Formation above the Ban
Member was excavated in April 2002 near Courtedoux west
Porrentruy in Canton Jura, at the site of a planned bridge
the Transjurane superhighway. Several of these footprin
were figured by Meyer & Thüring (2003, fig. 12).

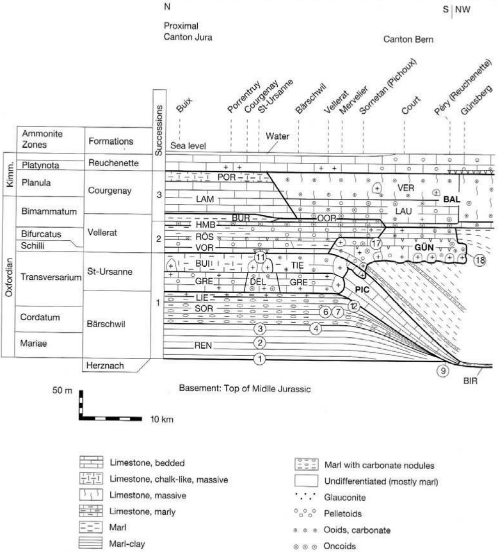
Before the author measured section RG 392 on the easte
flank of the northernmost part of Moutier gorge in 1983,
was told by his collegue B. Engesser that the bones of the lar
sauropod dinosaur *Ornithopsis greppini* von Huene that we
figured for the first time by Greppin (1870, pl. 1), were prob
bly found in the small quarry on the western brink of Mouti
gorge north of Moutier, Canton Bern. Thickly-bedded lim
stones of the lowermost Reuchenette Formation are expos
in that quarry at coordinates 595 330/237 550, east of Pâtura
du Droit. In section RG 392 on the opposite flank of t
gorge, three vast bedding planes are exposed in an old quar
above the cantonal road. The surfaces are in about the sa
level of the lowermost Reuchenette Formation as the beds th
are accessible in the quarry east of Pâturage du Droit. Ther
fore, the author searched the bedding planes of section R
392 for footprints of dinosaurs when he measured the secti
in June 1983. No unambiguous footprints were then found.

Section RG 392 begins beside the cantonal road at the elev
tion of about 500 m and ends at the elevation of about 580
at the top of a small cliff at the eastern face of the old quar
south of Arête du Raimeux. The cliff is formed by beds n
25–33 of the section and is up to 4 m high. The section is re
resented as plate 26 in Gygi (2000a). Section RG 392 is n
marked with an asterisk in table 1 in Gygi (2000a). This mea
that the entire section was measured without using a ro
Meyer & Thüring (2003, fig. 9) published an aerial view of t
upper bedding plane of bed no. 24 in section RG 392. Th
stated on page 110 that there are about 2000 footprints of
nosaurs on that vast surface. The surface is easily accessi
where it touches the footpath leading from the cantonal ro
up to Combe du Pont. The author could again find no fo
prints when he scanned part of the surface on 11 June 20
That visit was made, because Meyer & Thüring (2003, fig.
published a photograph of what they interpreted to be
footprint on the upper surface of bed no. 24. The location
this depression in the bedding plane is not indicated on th
figure 9.

Times of relatively wet or relatively dry climate were of
equal duration. Deposition of the argillaceous Bärschwil F
mation in a humid climate lasted almost two million ye
(fig. 185). The carbonate Hauptmumienbank Member of
Vellerat Formation with pseudomorphs of calcite after cal
um sulfate in the interior of oncoids (Gygi & Persoz, 1987,
2C) that are indicative of a drier climate, was laid down duri
a time of maybe only about 100 000 years, to judge from
time scale represented in figure 185.

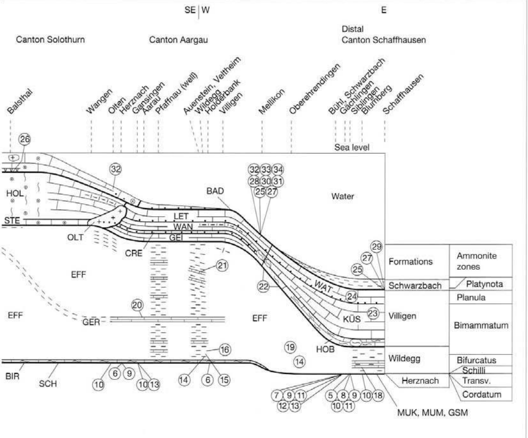
The climate in northern Switzerland during Late Jurassic ti
was seasonal as it is for instance in Bermuda today. This can
said, because some corals of the St-Ursanne Formation h
distinct accretion bands (fig. 172). In Bermuda, tropica
warm summers alternate with cool winters. Freezing air te
peratures can occur during particularly cold winters. R

corals of Bermuda have distinct accretion bands that record seasonal variation of the growth rate like in the trunks of trees growing in temperate or cool climates. Accretion bands become discernible only when there is more than a minimum of climatic change over the year. By counting accretion bands, Iams (1969) studied the growth rate of corals on shipwrecks around Bermuda of which he knew the year when the ships ran aground. One of these ships called Madiana was wrecked in 1903 on the reef that forms the northern rim of the Bermuda atoll (Iams, 1969, fig. 1). Colonies of the brain coral *Diploria strigosa* (Dana) were photographed on the Madiana shipwreck in the summer of 1968 by Gygi (1969b, fig. 12). The largest of the photographed colonies were then less than 65 years old. A *Diploria strigosa* with about the same diameter as the largest colonies of this taxon found on the Madiana wreck was collected by the author on Grid Reef in the lagoon of Bermuda. The position of that reef that was informally named by participants of the Organism-Sediment Seminar held by R.N. Ginsburg in 1968 at Bermuda, is indicated on a map by Gygi (1975, fig. 1). The colony of *Diploria strigosa* from Grid Reef that is now in the Museum of Natural History, Basel, was then sawed through the centre. 48 growth bands could be counted on the cut surface that have a thickness of between 3 and 5 mm. This compares well with the average of 3.2 mm of annual accretion measured by Iams (1969) on *Diploria strigosa* from different localities in Bermuda. The accretion bands of the thick branches of the coral *Cryptocoenia limbata* Goldfuss from a bioherm of the upper St-Ursanne Formation as figured by Gygi & Persoz (1987, fig. 3) that are refigured here (fig. 172) are 4–6 mm thick. These bands most probably document the amount of yearly accretion of aragonite and consequently a seasonal climate.



BAD	Baden Member
BAL	Balsthal Formation
BIR	Birmenstorf Member
BUI	Buix Member
BUR	Bure Member
CRE	Crenularis Member
DEL	Delémont Member
EFF	Effingen Member
GEI	Geissberg Member
GER	Gerstenhübel Beds
GRE	Grellingen Member
GSM	Glaukonitsandmergel Bed
GÜN	Günsberg Formation
HMB	Hauptmumienbank Member
HOB	Hornbuck Member
HOL	Holzflue Member
KÜS	Küssaburg Member
LAM	La May Member
LAU	Laufen Member
LET	Letzi Member

Fig. 173. Litho- and biostratigraphy of formations, members and beds of Late Jurassic age in northern Switzerland.
The section is palinspastic and is drawn perpendicularly to depositional strike. The encircled numbers are those of the ammonites listed in fig. 174. The base of the section is the bathymetric profile of the seafloor as it probably existed at the beginning of the Late Jurassic. This corresponds to fig. 187A. The represented thicknesses of the lithostratigraphic units are those that were measured in a great number of sections and then averaged. The water depth above the right part of the



~ ~ Siliceous sponges

Sponge bioherm

+ + Scleractinian corals

Coral bioherm or reef

2 *In situ* position of ammonite specimen of a taxon listed in figure 174

Intertidal and supratidal facies

EFF Abbreviated name of lithostratigraphic unit (see below)

LIE	Liesberg Member	SOR	Sornetan Member
MUK	Mumienkalk Bed	STE	Steinebach Member
MUM	Mumienmergel Bed	TIE	Tiergarten Member
OLT	Olten Member	VER	Verena Member
OOR	Oolithe rousse Member	VOR	Vorbourg Member
PIC	Pichoux Formation	WAN	Wangen Member
POR	Porrentruy Member	WAT	Wangental Member
REN	Renggeri Member	WET	Wettingen Member
RÖS	Röschenz Member		
SCH	Schellenbrücke Bed		

section is therefore apparent in this figure and is much greater than it probably was during deposition of the Baden Member and the Schwarzbach Formation. Differential, endogenic and exogenic basement subsidence during depositon of successions 1–3 and probable water depth at successive stages of sedimentation can be read from fig. 187B–D. The bathymetric profile as it is assumed to have existed at the end of deposition of succession 3, and the topography of the basement at that time that resulted from differential endogenic and exogenic subsidence is represented in fig. 187D.

8. Palaeoecology used as a key to sedimentary geology: A summary and evaluation of previous work

The main purpose of this chapter is to present evidence that water depth is an important factor controlling both sedimentation and the composition of the macrofauna. An attempt is made to monitor and quantify in terms of palaeodepth the lateral facies transition from the shallow-water upper St-Ursanne Formation to the deeper marine Birmenstorf Member (Middle Oxfordian). Another object is to assess the palaeobathymetry of faunal spectra of the Early Kimmeridgian in northern Switzerland and to compare this with the conclusions of Ziegler (1967, fig. 11).

8.1 Methods of palaeoecology

8.1.1 Facies analysis

The pattern of facies represented in figure 173 is compiled from the 221 detailed sections listed with coordinates in Gygi (2000a:12). In that book, a short description of the main facies is given and the most important sections measured in northwestern Switzerland are drawn in plates. The sections were measured in an area that begins in the west at a line between Biel and Boncourt. The area studied since 1962 extends from the west through Canton Jura, Bern, Solothurn, Basel-Landschaft, Aargau and Schaffhausen to Möhringen on the Danube river in southern Germany in the northeast. 2338 thin sections and numerous polished slabs were studied. The whole macrofauna including more than 9000 ammonites, about 6000 of them prepared, was evaluated for facies analysis.

8.1.2 Time correlation

Biochronology with macrofossils was the method initially used in order to establish time stratigraphy in the sediments studied here. Ammonites are the element of the macrofauna with the greatest rate of evolution. A resolution to the ammonite subzone could be achieved with the ammonites collected *in situ* in the Upper Jurassic of northern Switzerland. An ammonite subchron as discerned here lasted on the average about 300 000 years (fig. 175).

The sediments from deeper water could all be biostratigraphically dated with ammonites (fig. 173–174). However, there are great differences in ammonite abundance between individual lithostratigraphic units from deeper water. For instance, the thin, condensed Mumienkalk Bed (Gygi, 2000b:136) includes a rich ammonite fauna. On the other hand, there are very few ammonites in the middle and in the upper part of the thick Effingen Member that was laid down at a high sedimentation rate (Gygi, 1999, fig. 2). This makes detailed time correlation with ammonites difficult even in some parts of the deeper marine facies. Ammonite biostratigraphy becomes very incomplete in sediments from shallow water. For instance, no ammonites are known from the calcareous oolite of the Steinebach and of the Verena Member or from the peritidal, mostly micritic limestone of the Vorbourg Member. Other means of time correlation are necessary in such lithostratigraphic units.

Bolliger & Burri (1967) used detrital quartz and feldspar for time correlation that are concentrated in certain beds of the Röschenz and of the Effingen Member. Detrital quartz is rare or absent in limestone units like the St-Ursanne, Balsthal and the Villigen Formation, but clay minerals occur in amounts sufficient for X-ray analysis even in cleanly washed calcareous oolites with a secondary cement as for instance the Verena Member. Persoz in Gygi & Persoz (1986, fig. 10) found that the clay mineral kaolinite is especially suitable for time correlations. These authors first calibrated the highs and lows in the vertical variation of kaolinite abundance with ammonite biostratigraphy in Canton Aargau. Then they found that some conspicuous maxima and minima of kaolinite abundance could be correlated between deeper marine facies and shallow-water facies and even with terrestrial sediments (Gygi & Persoz, 1986, pl. 1). Time-stratigraphic correlations in marine, shallow-water facies with clay minerals were later checked and could be confirmed with the few ammonites that are known from carbonate platform sediments (Gygi, 1995).

Time stratigraphy of Gygi's sections was further refined with the method of sequence stratigraphy by P.R. Vail and A.L. Coe who both studied the most instructive sections in the field. The result was published by Gygi et al. (1998). Previously known marker units like the Hauptmumienbank Member or the Knollen Bed (Gygi, 2000b) could be proved to be isochronal by means of clay mineral and sequence stratigraphy. Attempts to measure numerical ages of some beds where authigenic glauconite pellets occur both within steinkerns of ammonites and in the embedding sediment were made by Gygi & McDowell (1970), and again by Fischer & Gygi (1989). The measured ages proved later to be too young (see below).

8.1.3 Water depth

8.1.3.1 Qualitative evidence of water depth

A supratidal, terrestrial environment is documented by the palaeosol with rootlets in the Röschenz Member of section RG 398 near Liesberg that was figured by Gygi (2000a, fig. 25). Calcareous nodules with a diameter of 4–10 cm in greenish-grey marl below a thin layer of lignite as they occur in bed no. 79 of section RG 390 in Moutier gorge (Gygi, 2000a:38, pl. 27) are interpreted to be calcrete (caliche). Similar, but microsparitic nodules in marl at the base of the Reuchenette Formation near Balsthal are covered with a layer of acicular calcite crystals that are arranged with the long axis perpendicularly to the surface of the nodule (fig. 175). The calcite rays represented in figure 176 are from a palaeosol above the Steinebach Member, bed no. 40 B, in section RG 4 near Waldenburg, Canton Basel-Landschaft. The rays of the figured rock sample Gy 49 include some detrital quartz grains that were observed in the thin sections Gy 2480 and Gy 2481. The quartz grains are interpreted to be evidence that the calcite rays grew within preexisting sediment. These calcite rays are therefore of different origin than the rays that were figured and called raggioni by Mutti (1994, fig. 10). Mutti's rays grew in empty cavities of a palaeokarst. Further evidence that the

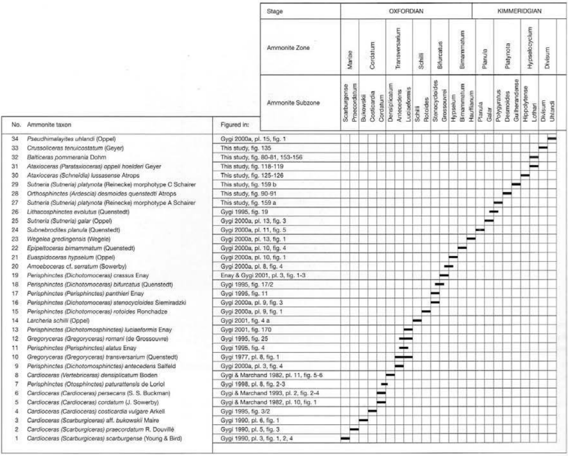


Fig. 174. Succession in time of ammonite taxa that were found in northern Switzerland and that are diagnostic of ammonite chrons and subchrons.

The listed ammonites were figured in the publications referenced after the name of the pertinent taxon. The numbers of the taxa correspond to the encircled numbers represented in fig. 173 that indicate the position of the ammonites in the lithostratigraphic units.

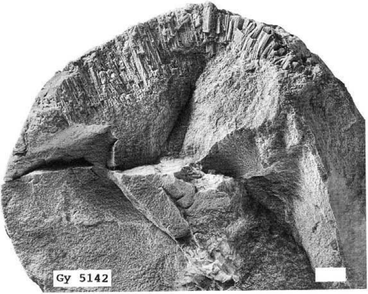


Fig. 175. Presumed calcrete nodule with radial calcite rays below the surface, from what is probably a palaeosol at the base of the Reuchenette Formation at Innere Klus near Balsthal, Canton Solothurn.
Rock sample Gy 5142 from bed no. 15 of the unpublished section RG 439. Scale bar is 1 cm.

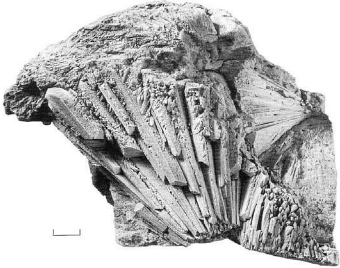


Fig. 176. Calcite rays from what is presumed to be a palaeosol above the Steinebach Member in the unpublished section RG 4, bed no. 40 B, rock sample Gy 49, Brocheni Flue near Waldenburg, Canton Basel-Landschaft. Scale bar is 1 cm.

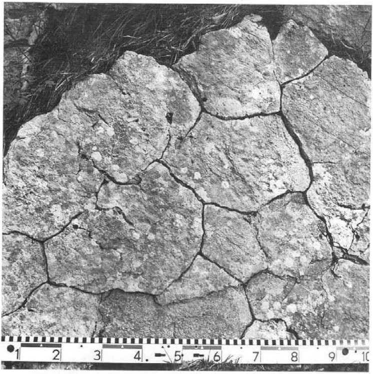


Fig. 177. Mud (prism) cracks on the upper surface of bed no. 42 in the unpublished section RG 417 on the south slope of Mt. Raimeux north of Crémines, Canton Bern.
The bed is an intertidal, laminated stromatolite that is documented by the polished slab Gy 4831. Scale is in decimeters. Refigured from Gygi (1992, fig. 5).

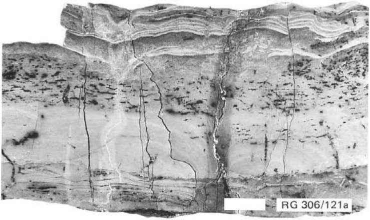


Fig. 178. Stromatolite that grew in the upper intertidal zone.
Polished slab Gy 4558 collected from the Vorbourg Member in section RG 306, bed no. 121a, near Liesberg, Canton Basel-Landschaft. Section RG 306 is represented in pl. 31 by Gygi (2000a). Indistinct domal structure of the stromatolite is visible above the flat-laminated base. Dark birdseye pores are above the domes. Thin, sub-vertical dewatering cracks are widest in the middle of the stromatolite. Refigured from Gygi (1992, fig. 10). Scale bar is 1 cm.

calcareous nodules covered with calcite rays that are represented in figure 186 from bed no. 15 of the unpublished section RG 439 near Balsthal were formed in a palaeosol is the pronounced relief above which the presumed palaeosol with the nodules was formed. This relief that is probably the result of subaerial erosion is well visible at the cliff of Chluser Roggen near Balsthal (Gygi, 2000a, fig. 37).

The thin layer of lignite (rock sample Gy 7722) at the upper surface of bed no. 80 in section RG 390 near Moutier (Gygi, 2000a, pl. 27) is also of supratidal origin. Limnic ostracods and gyrogonites of characean algae (Oertli & Ziegler, 1958, pl. 1) as well as land plants (Allenbach & van Konijnenburg-van Cittert, 1997) can be transported into the marine environment as was documented by Pümpin (1965, fig. 21). They are therefore disregarded here as indicators of a terrestrial environment.

Evidence of marginal marine, intertidal environments are bedding planes of calcareous mudstone with mud cracks (fig. 177) or calcareous stromatolites with mud cracks and birdseye pores (fig. 178). According to Shinn (1968), birdseye pores are unequivocal evidence of the intertidal environment. Prism cracks in intertidal lime mud probably evolve in most cases in the upper part of tidal flats that remain exposed during long intervals and are only flooded by particularly high (spring) tides. However, it must be borne in mind that Hardie & Garrett (1977, fig. 28) found "polygonal" cracks many tens of centimeters deep on the arched surface of intertidal bars within tidal channels on the carbonate tidal flats west of the northern part of Andros Island, Bahamas. The authors stated that the bars are exposed as much as 90% of the time, but that the bars are apparently regularly flooded at high tide.

Prism cracks also occur on the surface of argillaceous mud, but they could not be observed directly. Such cracks were found to be preserved as molded ridges at the underside of a stromatolitic layer of lime mud with a thickness of about 4 cm above marl. The marl-limestone boundary is clear-cut. The ridges are visible on the lower bedding plane of rock sample Gy 3690 of bed no. 57 in the unpublished section RG 320 that was measured along a forest road at Montépoirgeat on the western flank of Sorne gorge north of Undervelier, Canton Jura. Gygi (1992) documented that stromatolites in themselves give no information of palaeodepth, because they occur down to the floor of the epicontinental basin of the Late Jurassic in northern Switzerland.

A shallow-marine, subtidal environment is commonly concluded in Jurassic sediments from the presence of ooids, both calcareous and ferriferous. In the Recent, calcareous ooids were documented by Eardley (1938) to grow in Great Salt Lake in Utah, USA. But by far the greatest part of Recent calcareous ooids is accreted in the very shallow-marine environ-

Fig. 179. Aerial view of some islands of the Joulters Cays north of Andros Island, Bahamas.
The view is towards the bank interior. To the left of the nearest island is a tidal channel (dark strip). The channel is about 4 m deep, and small coral reef knobs (not visible on the photograph) grow in it. To the left of the channel and at its distal mouth in the foreground is a white sand shoal where calcareous ooids are accreted at the present time. Hermatypic corals (dark) grow on the level seafloor at a depth of several meters in the nearest foreground.

ment on the Bahama Bank and in the nearshore waters off the southern shore of the Persian Gulf.

Newell & Rigby (1957, fig. 1) presented a map of the areas where in the Recent, calcareous ooid sand is accreted in the Bahamas. Plate 22 in that study is a map of the Joulters Cays north of Andros, the largest island of the Bahamas. Figure 179 in the present study is an aerial view of an island of the Joulters Cays and of an active ooid sand shoal adjacent to a tidal channel. The following photograph of figure 180 was taken at low tide on the sand shoal that is represented in aerial view to the left of the tidal channel in figure 179. The sample Gy 7724 of Recent ooid sand from that locality is kept in the Museum of Natural History, Basel. Newell & Rigby (1957, pl. 14:2) gave a photograph of Recent, loose ooid sand that they collected near the Joulters Cays. Figure 3 on the same plate shows such ooids in thin section. Purdy (1963:478) stated that Bahamian ooid sand is mostly accreted near the margin of the banks at a depth ranging from 4 to 6 m, but that it can also be formed in the bank interior in water only 1–2 m deep.

Off the southern shore of the Persian Gulf, calcareous ooids are mainly accreted where strong tidal currents roll them regularly. Loreau & Purser (1973:285) found that the most prominent areas of ooid formation are tidal deltas (op.cit., fig. 4), but they stated that ooids can also be formed in highly protected lagoons (op.cit., p. 289, fig. 1). The authors indicated on page 319 that ooid formation is confined to water depths of less than 5 m. Wagner & van der Togt (1973:140) concluded that calcareous ooids can be accreted down to a maximum water depth of only 3 m. Loreau & Purser (1973:316) showed that the ultrastructure of the outermost cortex of calcareous ooids is diagnostic of the environment of formation. The cortices are aggregates of aragonite needles. Tangential orientation of the needles is evidence of moderate to strong agitation of the water. Radially oriented needles indicate feeble agitation. The diagnostic ultrastructure can be partly preserved when aragonite needles in ooids are transformed into low magnesian calcite in the course of diagenesis (Gygi, 1969a, pl. 9:34 and 36).

The major bodies of calcareous oolite of Late Jurassic age in northern Switzerland that are represented in figure 173 were therefore formed in a shallow-marine environment. Small coral bioherms that are embedded in calcareous oolite of the Tiergarten Member in the distal part of the upper St-Ursanne Formation, for instance near Grellingen, Canton Basel-Landschaft, are additional evidence of this. Similar, small bioherms were found in the calcareous oolite of the Verena Member of the upper Balsthal Formation. A possible Recent counterpart of such small reef knolls are the bioherms growing in a tidal channel with a depth of 3–4 m between an active oolite shoal and an island of the Joulters Cays north of Andros Island, Ba-

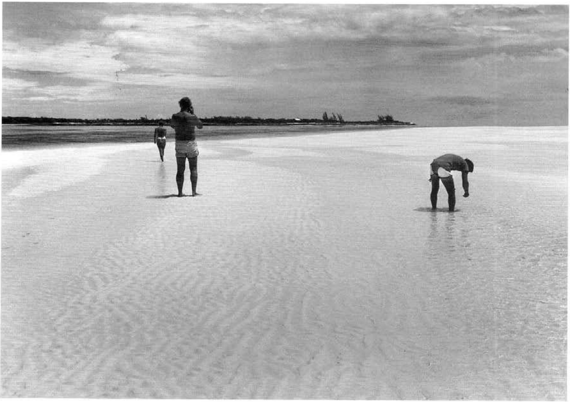


Fig. 180. Active shoal of calcareous ooid sand, Joulters Cays, Bahamas, photographed at low tide.
The ooid sand is partly emergent and is finely rippled. The tidal channel and the island in the background are those shown in fig. 179.

hamas (fig. 179). The reefs are not visible on the photograph. A possible tidal delta of calcareous ooid sand in the uppermost Günsberg Member near Péry, Canton Bern, is 5.7 m thick (section RG 307, beds no. 193–195, see Gygi, 2000a, pl. 22). The foresets of the delta are inclined in different directions as is visible in figure 181 of this study. The foresets indicate that the thickness of the delta is roughly equivalent of the depth of the water the delta was shed into. A thin section photograph of bed no. 193 in the oolitic tidal delta near Péry is figure 13 in Gygi (2000a). Ammonites are very rare or absent in calcareous oolite. The few specimens that were found are not well-preserved (Gygi, 1995, fig. 19–20).

Iron-bearing ooids are nowhere accreted in Recent seas. At the present time, they are only formed in the limnic environment of Lake Tschad south of the Sahara desert (Lemoalle & Dupont, 1973). Iron oolite is quantitatively unimportant in the studied, marine rocks of the Late Jurassic. Gygi (1981) reviewed and discussed what was published on the origin of iron oolite until 1979. The iron-ooids investigated in sediments of Late Jurassic age in northern Switzerland occur in thin, widespread beds at the base of the sediment stack that was laid down in Late Jurassic time. The beds have a matrix of argillaceous or calcareous mud. The muddy matrix is evidence that the environment of deposition was normally quiet. The iron-ooids must have been rolled and accreted by episodic, oscillating currents, probably during storms. The iron-ooids cannot have been brought into the environment by unidirectional currents from elsewhere, because such currents would have swept away the embedding mud. The iron-ooids were therefore accreted at the surface of mud and finally embedded within mud in one and the same environment. Ammonites are common or prevail in the macrofauna of these iron oolites (Gygi, 1999, fig. 2). This is evidence of relatively deep and well-aerated water. The state of preservation of the ammonites is often very good (Gygi & Marchand, 1982). Brown, goethitic iron-ooids are most common in the beds (Gygi, 2000a, fig. 9), but green, chamositic iron-ooids can be formed in the same, open-marine environment (Gygi, 1969a, pl. 3:8).

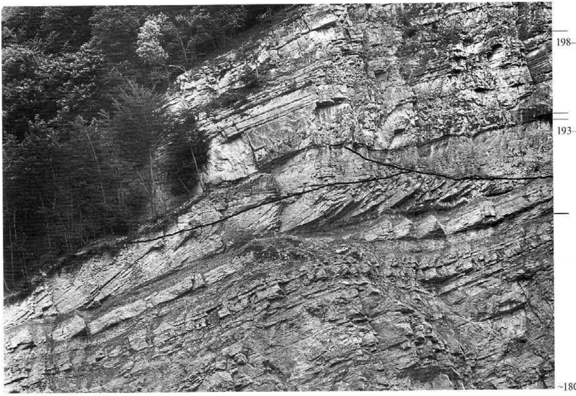


Fig. 181. Cliff at the northern face of the quarry La Charuque south of Péry, Canton Bern, as seen from the quarry floor further south.

The photograph shows part of section RG 307 that was drawn in detail by Gygi (2000a, pl. 22). The numbers on the right margin of the photograph correspond to the numbers of the beds discerned in section RG 307. Beds no. 193–195 are a set of prograding foreset beds of calcareous oolite with a *depositional* dip to the left, on the left (western) side of the photograph. These foreset beds are truncated by two successive, oblique erosional surfaces that descend to the right in the photograph (bold black lines). Above the truncation surfaces are foreset beds with a depositional dip to the right (south). The succession 193–195 has a total thickness of 5.7 m. It is a tidal delta that was intersected by a laterally shifting tidal channel. The channel was filled in by subsequent foreset beds. The upper surface of succession 193–195 is hummocky and is covered with a limonitic crust. The corresponding, probably coeval erosional surface is easily accessible beside the cantonal road east of Liesberg in section RG 441 that was figured by Gygi & Persoz (1987, fig. 2A). Gygi (2000a, pl. 22) erroneously labelled succession 193–195 in section RG 307 near Péry "Steinebach Member". Beds no. 198–211 above belong to the Hauptmumienbank Member that is not indicated in pl. 22 by Gygi (2000a).

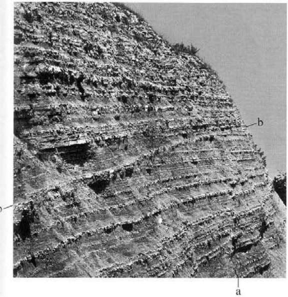


Fig. 182. Synsedimentary fault (a) in the lower right part of the figure and a submarine truncation surface (b–b) to the left of the fault.
Upper Effingen Member in the quarry of Jakobsberg near Auenstein, Canton Aargau: upper part of section RG 37.
Refigured from Gygi & Persoz (1986, fig. 2).

A submarine, depositional slope is documented by truncation surfaces (see fig. 182) and by associated debris flows that were both figured by Gygi & Persoz (1986, fig. 2–3). Debris flows can grade distally into small turbidites (Kelts & Hsü, 1980). A small, graded turbidite from section RG 68 in the Effingen Member near Rekingen, Canton Aargau, was figured by Gygi (1969a, pl. 4:12). Such turbidites are an indication of a water depth of tens of meters at least.
Tempestites (storm layers) are common in sediments from shallow water. The eight, laminated, superimposed tempestites in the uppermost exposed, marly part of the Günsberg Formation in section RG 14 in the landslide Gschlief above Günsberg, Canton Solothurn, are good examples, especially the polished slab Gy 190 from bed no. 179 (unpublished). The section is represented in detail in Gygi (1969a, pl. 18). Tempestites that were sedimented in shallow water below coral bioherms are conspicuous in the uppermost part of the Effingen Member in section RG 307 in the quarry La Charuque near Péry, Canton Bern (Gygi, 2000a, pl. 22). Bed no. 160e beside a coral bioherm in that section is a typical tempestite (polished slab Gy 3452) that was figured by Gygi (1986, fig. 7). According to Gygi (1981), storms could resediment sand-grade particles at a depth of as much of 100 m. Thin, laminated beds including much fine-grained detrital quartz in the lower Effingen Member that were laid down at a depth of about 100 m were interpreted to be tempestites by Meyer (1984). One of these, the laminated, sandy bed with numerous, very well-preserved starfish in the uppermost part of Schofgraben on Mt. Weissenstein, on the territory of the village of Rüttenen, Canton Solothurn, is here interpreted to be rather a turbidite (see below). The fact that it can be difficult to discern deep-water tempestites from turbidites is reason to disregard tempestites as indicators of water depth.
Authigenic, pure glauconite pellets with swelling cracks at the surface were figured by Gygi (1969a, pl. 4:15) and by Fischer & Gygi (1989, fig. 7). They occur isolated in the mud matrix of thin beds that were, according to the ammonites that prevail in the macrofauna, sedimented in relatively deep water. Such fully evolved glauconite pellets are as much as 30% by volume of the Glaukonitsandmergel Bed in Canton Schaffhausen. Gygi (1969a:18 and pl. 3:9) figured biotites from the lower Birmenstorf Member that were preserved at different stages of glauconitization. Presence of unaltered biotite grains in the Glaukonitsandmergel Bed is evidence that probably most of the glauconites in the bed were formed by transformation from biotite as Galliher (1935) described it from the Recent in Monterey Bay, California. During the process of glauconitization, the biotite grains swell, and fissures open at the grain surface. Fully evolved, mature glauconite pellets have the cauliflower aspect as was figured by Fischer & Gygi (1989, fig. 7). These mature, fossil glauconites are very similar to those as figured by Galliher (1935, fig. 12/14) from the Recent. Galliher (1935:1582) stated that glauconite becomes "very plentiful" in Monterey Bay from a depth of 50 fathoms, this is to say from about 90 m. A small portion of the glauconite grains that were separated by the author from the Glaukonitsandmergel Bed are faecal pellets to judge from their elongate, sausage-like shape.
The diameter of glauconite pellets can be as much as 450 microns. A study in thin section is necessary to prove that the pellets are homogenous (Gygi, 1969a, pl. 4:15, and Fischer & Gygi, 1989, fig. 8). Glauconite pellets are an aggregate of minute crystals that can only be discerned with the electron microscope. The size of the crystals is 1–3 microns (Gygi, 1969a, pl. 4:14, and Fischer & Gygi, 1989, fig. 9). Glauconites of the Glaukonitsandmergel Bed were analyzed chemically and with X-rays by Gygi & McDowell (1970) in order to date them radiometrically by the K-Ar method. Their age was revised by Fischer & Gygi (1989, fig. 3). The measured ages were later found to be too young (see below).
Glauconite was in some cases formed in the interior of fossils. Gygi (1969a, pl. 10:38) figured a small bioclast of an echinoderm with glauconite in the interior, and a small algal nodule that is partly replaced by glauconite from the Knollen Bed. Glauconite as a filling of thin algal tubes in minute oncoids occurs in the Crenularis Member of Canton Aargau (Gygi, 1969a, pl. 5:21). These glauconites were identified in thin section and with the electron microprobe. A large oncoid of Hypselocyclum age from bed no. 47 of section RG 28 near Schönenwerd with algal tubes filled with glauconite was figured by Gygi (1992, fig. 16–17). The mode of formation of glauconite within fossils is unknown. Such glauconites evolved in sediments from shallower water than the glauconites of the Glaukonitsandmergel Bed. Few, very fine-grained glauconite grains were identified in thin section Gy 6336 from the middle Vorbourg Member on Mont Chemin above Choindez near Courrendlin, Canton Jura (bed no. 15 of the unpublished section RG 376, a peloidal wackestone with oncoids up to 1 cm across). Most of the Vorbourg Member was laid down in the peritidal zone.
Zeiss (1955, fig. 31) documented that in the former opencut iron mine at the foot of Stoberg hill near Blumberg, southern

Germany, the vertical facies transition from the iron-oolitic Herznach Formation below to the glauconitic Glaukonitsandmergel Bed above occurred during the Lamberti Subchron at the end of the Middle Jurassic. The same vertical facies transition occurred in Canton Aargau and in eastern Canton Solothurn much later, probably at the time boundary between the Densiplicatum and the Antecedens Subchron (see below). Gygi (1981) concluded that in the marine environment, iron-ooids can be accreted from shallow water down to a depth of about 100 m, and that pure, fully evolved glauconite pellets that are isolated and in a mud matrix were formed at a depth greater than 100 m. If this be correct, then the water depth became greater than 100 m just before the beginning of the Late Jurassic near Blumberg north of Canton Schaffhausen, and exceeded 100 m much later, at the beginning of the Antecedens Subchron, in Canton Aargau.

Consequently, the water depth at the beginning of the Late Jurassic was greater in Canton Schaffhausen than in Canton Aargau (fig. 187A). The rate of sedimentation was minimal in both regions between the Late Callovian and the Antecedens Subchron of the Middle Oxfordian. According to Haq et al. (1987, fig. 4), a net eustatic sea-level rise occurred during this time. This was possibly combined with some regional subsidence of the basement (Wildi et al., 1989). The water depth therefore significantly increased with time both in Canton Aargau and in Canton Schaffhausen. The lateral transition from the iron-oolitic Schellenbrücke Bed in Canton Aargau to the coeval, glauconitic Glaukonitsandmergel Bed in Canton Schaffhausen is evidence that the difference in water depth between the two regions persisted from the beginning of the Late Jurassic at least to the Cordatum Subchron.

Sedimentation began at the onset of the Late Jurassic both in northwestern Switzerland and in Canton Aargau with a thin bed of argillaceous mud including iron-ooids. This bed can be followed from Liesberg, Canton Basel-Landschaft, section RG 280, base of bed no. 7 in Gygi (2000a, pl. 30) through Péry, Canton Bern, section RG 307, bed no. 20 in Gygi (2000a, pl. 22) to Ueken, Canton Aargau, section RG 208, bed no. 6 in Gygi (1977, pl. 11). Ammonites prevail in the macrofauna in all of the outcrops of this bed and document that the bed is isochronous where it occurs. The ammonites are of the Scarburgense Subchron and were figured by Gygi & Marchand (1982) and by Gygi (1990b). The very similar lithology and composition of the macrofauna of this bed is an indication that the depth of deposition did not vary significantly in the area where the bed occurs (fig. 187A).

The shallowing-upward, marl to limestone successions 1 and 2 that are represented in figure 173 were conceived by Gygi & Persoz (1986, pl. 1A). The averaged, combined thickness of successions 1 and 2 is almost exactly the same in northwestern Switzerland and in the region of Balsthal in Canton Solothurn (fig. 173). Sedimentation of succession 2 ended in northwestern Switzerland at the top of the Hauptmumienbank Member in a very shallow lagoon and near Balsthal at the top of the coeval Steinebach Member of calcareous oolite near sea level (fig. 173 and 187C). This is confirmed by a palaeosol above the Steinebach Member in section RG 15, bed no. 3 in the uppermost part of Horngraben, 7 km west-southwest of Balsthal, and by a palaeosol with calcite rays in section RG 4, bed no. 40B at Brocheni Flue near Waldenburg, Canton Basel-Landschaft (fig. 176). A break in sedimentation at the top of the

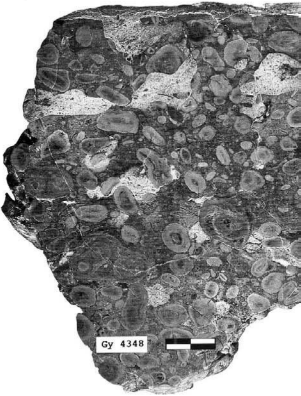


Fig. 183. Oncolite of the uppermost Hauptmumienbank Member, bed no. 50 of the unpublished section RG 372, that was measured along the road from Hautes Roches to Le Trondai near Roches, Canton Bern.

The top of the polished slab Gy 4348 figured here intersects a planed erosion surface. The surface and the borings descending from it cut across oncoids. Both the thickness of exactly 5 m and the facies of the Hauptmumienbank Member are typical at this locality (beds no. 49–50 of section RG 372). Nevertheless, Bolliger & Burri (1970:74) renamed the member "Hautes-Roches-Algenkalke" and included in their unit the Humeralis-Kalke of Ziegler (1956:58), now called Laufen Member, with what Ziegler appropriately called "accessory oncolites". Scale bar is 2 cm.

Hauptmumienbank Member is in some places documented by bored hardgrounds like at the top of bed no. 50 in the unpublished section RG 372 near Roches, Canton Bern (fig. 183). Time equivalence of the Hauptmumienbank Member and of the Steinebach Member is established by the mineral stratigraphic correlations H and I in plate 1A by Gygi & Persoz (1986) that are calibrated with ammonites.

The top of succession 1, this is to say the top of the St-Ursanne Formation, the Pichoux Formation and of the Birmenstorf Member, coincides with the top of the Transversarium Zone. This is documented by ammonites as figured by Gygi (1995) and by Gygi (2001) as well as by the mineral stratigraphic correlation C of Gygi & Persoz (1986, pl. 1A). The normal facies of the Birmenstorf Member with an average thickness of only 5 m includes mature glauconite pellets above the base, and a macrofauna with abundant siliceous sponges and ammonites. Siliceous sponges were probably more numerous than ammonites in the biocenosis of the Birmenstorf Member, but they are not included in most of the faunal spectra given or cited below because of their very variable state of preservation. There are all intermediate stages between whole sponge fossils and small tuberoids. Quantification of sponges in a given macrofauna is therefore uncertain.

The Tiergarten Member in the marginal part of the upper St-Ursanne Formation with coral bioherms within calcareous oolite indicates a water depth of less than 10 m. Sedimentation of the St-Ursanne Formation ended near sea level (fig. 178, 187B). It is evident from the geometry of the Pichoux Formation as represented in figure 173, that the formation was sedimented on a slope, that the argillaceous mud bank of the Bärschwil Formation below was a positive physiographic structure, and that a macrofauna with mainly ammonites and siliceous sponges is indicative of relatively deep water. Consequently, succession 1 in northwestern Switzerland is shallowing-upward just as succession 2 is near Balsthal.

8.1.3.2 Quantitative approach to water depth

Stromatolites with birdseye pores and mud cracks (fig. 177–178) are evidence of the upper intertidal zone. They are taken in the following estimates of depth as indicators of water depth zero. The top of succession 1 in northwestern Switzerland is assigned to the intertidal zone as an approximation even though the stromatolite shown in figure 178 was found a few meters above the top of the St-Ursanne Formation, within the Vorbourg Member. Water depth zero is also assumed for the top of the Balsthal Formation between Günsberg (section RG 14) and Mt. Rüttelhorn (section RG 440), see Gygi (2000a, fig. 1 and list of sections with coordinates on p. 12). The mappable boundary between the Balsthal Formation and the Reuchenette Formation (conspicuous in Gygi, 2000a, fig. 38) as it is indicated by Gygi (2000a, pl. 22, section RG 307 near Péry, and pl. 43, section RG 440 on Mt. Rüttelhorn near Rumisberg, both in Canton Bern), probably coincides with the boundary between the Planula and Platynota Zone. This can be concluded of the mineral stratigraphic correlation L in Gygi & Persoz (1986, pl. 1). The zero depth simplification is made even though the intertidal stromatolite of bed no. 236 in section RG 307 near Péry (polished slab Gy 3488, fig. 184) or of bed no. 20 in section RG 440 on Mt. Rüttelhorn (polished slab Gy 5157, not figured) is a few meters above the formation boundary. These stromatolites are assumed to be coeval with the palaeosol at the base of the Reuchenette Formation near Balsthal (Gygi, 2000a, pl. 44, section RG 438, bed no. 52) that is represented here in figure 175 from the unpublished section RG 439 near Balsthal. An ammonite of the early Platynota Chron (no. 26 in fig. 174) was found 2.6 m below the palaeosol by B. Martin and P. Tschumi in what is now bed no. 9 of the unpublished section RG 439 (see below). Studies on the Recent marine environment where calcareous ooids are formed agree that the ooids are accreted and sedimented at a water depth of less than 10 m (see above).

Gygi (1981) investigated the origin of iron-ooids in the upper Herznach Formation of Canton Aargau. Goethite or limonite

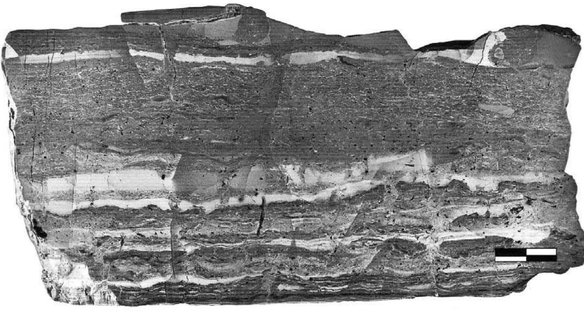


Fig. 184. Intertidal stromatolite from the lowermost Reuchenette Formation in the type section of the formation east of La Reuchenette near Péry, Canton Bern.
Polished slab Gy 3488 from bed no. 236 of section RG 307 (Gygi, 2000a, pl. 22). Scale bar is 2 cm.

is the quantitatively most important constituent mineral of the ooids (Gygi, 2000a, fig. 9), but, according to Gygi (1981:237), some of the ooids are partly or entirely green. This green material was called chamosite by Gygi (1981), although Gygi (1969a:19) made it plain that chamosite is a paragenesis that can include the minerals chlorite, kaolinite and what was then called montmorillonite. It must also be noted that the iron oolites directly below the Birmenstorf Member near Auenstein (Gygi, 1969a, pl. 2:4), Holderbank and Oberehrendingen (Gygi, 1969a, pl. 3:8) are now known to be of Bathonian age. This is documented by numerous ammonites from *in situ* that were figured by Mangold & Gygi (1997). It turned out that green iron-ooids are less common in the upper Herznach Formation than Gygi (1981) thought. But it is a fact that green iron-ooids with ferrous iron can be formed side to side with brown ooids with ferric iron in an open marine environment without a special submarine topography, and at a depth of tens of meters (Gygi, 1981, fig. 4). The predominance of ammonites in the macrofauna of the upper Herznach Formation is an indication of relatively great depth (Gygi, 1981, table 1). Relatively deep water is also indicated by the muddy matrix (Gygi, 2000a, fig. 9). The mud is evidence that the bottom water was normally quiet. Taphonomic analysis of the Schellenbrücke Bed revealed that the sediment was deposited below the wave base of normal storms, but that it was within reach of infrequent, but particularly strong storm waves (Gygi, 1981, fig. 3). This sets an upper limit to water depth for iron-ooid accretion. The maximum depth is where episodic, storm-induced, oscillating currents are never strong enough to roll particles the size of iron-ooids at the surface of muddy sediment (Gygi, 1981:248).

The ammonites as figured by Gygi & Marchand (1982) prove that the iron-oolitic Schellenbrücke Bed of Canton Aargau grades laterally into the Glaukonitsandmergel Bed with very abundant glauconite in Canton Schaffhausen. Gygi (1981, table 1) compared the macrofaunas of the two beds and interpreted them in terms of palaeodepth according to Ziegler (1967). He concluded that the ammonite assemblage of the Schellenbrücke Bed indicates a maximum depth of 100 m, and that the Glaukonitsandmergel Bed must have been deposited, also to judge from the composition of its ammonite fauna according to Ziegler (1967), at a depth that was considerably greater than 100 m (Gygi, 1981, fig. 4).

Glauconite pellets are as much as 30% by volume of the Glaukonitsandmergel Bed in Canton Schaffhausen, but they are very rare in the coeval Schellenbrücke Bed (Gygi, 1981:243). Glauconite is known to be abundant in sediments that were laid down at a low rate. Both the Schellenbrücke Bed and the Glaukonitsandmergel Bed are thin and were sedimented at a low rate. This calls for an explanation of the great difference in glauconite abundance between the two coeval beds. Kuenen in Cloud (1955:488) stated that Recent glauconite is formed in Indonesia, this is to say in the tropics, only at a water depth that is greater than 55 m. Porrenga (1967) studied Recent sediments off the Niger delta close to the equator in Africa. He found that substantial glauconite formation takes place there only from a minimum depth of 60–70 m downward, at a water temperature that is lower than 15 °C. Glauconite becomes abundant off the Niger delta only from a minimum depth of 125 m. The Niger delta is at a latitude of 4–5° north in a fully tropical sea. Northern Switzerland was in Late Jurassic time at about 35° north. Evidence was cited above that the subtropical belt must have been wider at that time than it is today. Nevertheless, the minimum depth of prolific glauconite formation was probably less in subtropical northern Switzerland during Late Jurassic time than it is in the Recent off the Niger delta that is near the equator. Following Gygi (1981:244), it is assumed that the transition between iron-oolitic and glauconitic facies with isolated, fully evolved glauconite pellets, is in sediments of Late Jurassic age in northern Switzerland at a palaeodepth of about 100 m. This depth was probably the same in vertical and in lateral iron oolite-glauconite facies transitions.

It follows from this that the lateral transition from the Schellenbrücke Bed with iron-ooids to the Glaukonitsandmergel Bed with very abundant glauconite is indeed the effect of increasing water depth. If this is so, then the vertical transitior from iron-ooid formation in the Herznach Formation neaı Blumberg to the growth of glauconite pellets in the Glaukonitsandmergel Bed above was caused by an increase in wateı depth with time, when the sedimentation rate was minimal (se below). The succession of facies near Blumberg is then inverse with the Glaukonitsandmergel Bed from deeper water bein above the Herznach Formation that was deposited in shallower water. This vertical transition occurred near Blumberg a the beginning of the Late Jurassic.

The bathymetric range in which marine iron-ooids could b accreted in the studied sediments is then between very shallo water (see below) and about 100 m. Mature, cauliflower glau conite pellets were formed in the studied sediments from depth of about 100 m downward. It cannot be decide whether the two depth ranges touched each other or whethe they slightly overlapped (see discussion in paragraph 9.15 o palaeobathymetry).

8.1.4 Subsidence: endogenic and exogenic

8.1.4.1 Endogenic subsidence

Deposition of succession 1 ended in northwestern Switzerlan probably in the intertidal zone (see above). Shallow-marin peritidal and partly terrestrial sedimentation of successions and 3 above was therefore possible only if the basement sul sided independently of sedimentation, as caused by process in the earth interior. This process of basement subsidence w called *endogenic* by Gygi (1986:469). It was formerly call tectonic subsidence (see below). This type of subsidence northern Switzerland may have been a side effect of spreadi of the Tethys in Late Jurassic time (Wildi et al., 1989). If t rate and amount of endogenic subsidence was everywhere t same, then the carbonate platform sediments of the St-U sanne Formation or of the Balsthal Formation would have t same thickness in all of the measured sections. In fact, the S Ursanne Formation is about 95 m thick in section RG 3 across the ridge of Chestel near Liesberg, Canton Basel-Lan schaft (Gygi, 2000a, pl. 31). Only 4.5 km to the north-nort west, in the unpublished section RG 397 west of Schlossfels near Kleinlützel, Canton Solothurn, the thickness of the S Ursanne Formation is but 35 m (see above). This is eviden that endogenic subsidence at a given time could vary grea over short horizontal distances during sedimentation (Gy 1990c, fig. 5).

8.1.4.2 Exogenic subsidence
When a major amount of sediment is laid down, then the weight of the sediment causes the basement to subside isostatically. If there are older sediments below, then basement subsidence is further enhanced by the compaction of mud in those deposits because of loading with younger sediments. Significant basement subsidence can also be caused by the loading of the lithosphere with additional water by a long-term, net relative sea-level rise. This was the case in the epicontinental basin in Canton Schaffhausen, where sedimentation of succession 1 during a time of about 2.4 million years (Gygi, 1999, fig. 3) amounted to but 0.5 m in section RG 81b near Gächlingen (Gygi, 1977, pl. 11). The combined process of loading of the basement with sediments, or with water by eustatically rising sea level, and of load-induced compaction of older, mainly mud-grade sediments below as caused by the weight exerted on them, is called *exogenic* subsidence. Detailed calculation of both endogenic and exogenic subsidence in northern Switzerland during the Late Jurassic was attempted by Gygi (1986). This should be checked in the future by the more general method of backstripping that was used by many authors, as for instance by Steckler & Watts (1978, fig. 6).
The measured thicknesses of some of the lithostratigraphic units are averaged in order to smooth the effect of differential synsedimentary tectonics as mentioned above. Great care was taken to measure the thickness mainly of carbonate platforms as exactly as possible in the field. For instance, the type section RG 438 of the Balsthal Formation in Gygi (2000a, pl. 44) was measured along the road through Steinebach gorge north of Balsthal, Canton Solothurn. This road intersects the vertical, massive Holzflue Member at a very oblique angle. Therefore, measurement of thickness was difficult, and the possibility of an error had to be envisaged. Therefore, the thickness of the member was checked by measuring the nearby, unpublished section RG 450 on the rope (Gygi, 2000a, fig. 4 and 37) at Chluser Roggen near Balsthal. Finally, it is certain that isostatic adjustment of the lithosphere as caused by loading with sediments or water was much faster than sedimentation rates or the rate of relative sea-level rise, respectively, so that sedimentation rates do not have to be taken into account (see below, and Gygi, 1986:471). The great differences in thickness over short horizontal distances that were found in limestone formations and members (see below) could only be produced by fractures in the lithosphere at close intervals, not by flexural deformation.

8.1.5 Relative sea-level changes

Endogenic subsidence combined with nondeposition, a low sedimentation rate, or with a long-term, net eustatic sea-level rise, result in what is called relative sea-level rise. If the average rate of sedimentation is lower than the average rate of net relative sea-level rise, then the water becomes deeper as was the case when succession 1 was laid down in Canton Schaffhausen (fig. 187A–B, and Gygi, 1999, fig. 3). The maximum water depth was assumed by Gygi (1999, fig. 3) to have exceeded 160 m at the end of deposition of succession 1 in Canton Schaffhausen. According to current knowledge, this depth was less (this study, fig. 187B). There are no natural outcrops of succession 1 in Canton Schaffhausen where the succession is on average only about 0.5 m thick.

In Canton Aargau, succession 1 is well-exposed and easily accessible in section RG 226 in a road cut that was dug after 1967 when the author finished the manuscript of Gygi (1969a). The cut is between the quarry Unteregg in the Hauptrogenstein Formation south of Veltheim and the quarry Jakobsberg in the Wildegg Formation east of Auenstein, Canton Aargau (Swiss topographic map 1:25000, sheet no. 1089 Aarau). The bioclastic calcarenite of the Early Bathonian Spatkalk Member is 3.2 m thick in this section Gygi (1973, fig. 3, bed no. 25). This unit is a tidal delta with inclined foresets on the eastern flank of the road cut. The inclined bedding is not visible on the western flank of the cut (fig. 10 in Gygi et al., 1998). Sedimentation of the Spatkalk Member ended probably in the intertidal zone. The top of the member is covered with a limonitic crust. Above the crust is a marine oolitic ironstone with a total thickness of about 25 cm (Mangold & Gygi, 1997, fig. 2). These authors figured several ammonites of the Middle Bathonian Subcontractus Chron from the iron oolite (bed no. 28 of section RG 226, op.cit. fig. 3:3, 3:5, 3:6 and 3:8). Ammonites and the brachiopod *Rhynchonelloidella alemanica* (Rollier) are fairly common in this bed, but bivalves prevail in the macrofauna as is documented by the large ostreids in the polished slab Gy 3099 that is represented in figure 28 by Gygi (1992). This is an indication that the water was between 20 and 30 m deep (see below) when the iron oolite was formed in the Middle Bathonian.
Gygi (1969a, pl. 2:4), for lack of ammonites in the figured drill core that is from the same locality near Veltheim, assigned the iron oolite mentioned above to the Callovian and to the latest part of the Early Oxfordian. The reason for this was that he found the *Cardioceras (Cardioceras) persecans* (Buckman) of the Cordatum Subchron with the original number Gy 663 a few kilometers to the east in the uppermost part of the corresponding iron oolite in section RG 39, bed no. 1, near Lupfig east of Holderbank, Canton Aargau. This ammonite was for many years the only one known from the iron oolite directly below the Birmenstorf Member between Veltheim and Oberehrendingen. The ammonite has now the individual number J 30723 and is the only one that was found in bed no. 1 of section RG 39. It was figured by Gygi & Marchand (1982, pl. 9:1). It is now probable that this ammonite was fossilized during the Early Oxfordian in a lens that could not be discerned lithologically from the older iron oolite of Middle Bathonian age around the lens. The thin iron oolite between the Spatkalk Member below and the Birmenstorf Member above between Veltheim and Oberehrendingen is all of Middle Bathonian age, to conclude from the ammonites that were figured by Mangold & Gygi (1997) from this bed in sections near Veltheim, Holderbank and Oberehrendingen.
Above the iron oolite in section RG 226 near Veltheim is a laminated, microbialitic crust with a thickness of several millimeters (Gygi, 1992, fig. 28–29). The crust is mostly chamositic, but it is partly limonitized. The crust was formed in normally aerated seawater, possibly below a microbial mat that provided for the mildly reducing microenvironment that was the condition for chamosite formation (see Burkhalter, 1995:70). According to the cardioceratid ammonite J 30723 from Lupfig that was fossilized in an iron-oolitic lens directly *below* the crust, the crust was formed at the end of the Cordatum Subchron of the Early Oxfordian. The time equivalent of

the crust in Canton Aargau is in Canton Schaffhausen the oxidized uppermost part of the Glaukonitsandmergel Bed that is dated at the Cordatum Subzone by the *Cardioceras (Cardioceras) persecans* (Buckman) J 23008 that was figured by Gygi & Marchand (1982, pl. 9:3) from bed no. 12 of section RG 81b near Gächlingen (Gygi, 1977, pl. 11).
Above the crust in section RG 226 near Veltheim, Canton Aargau, is the marker bed at the base of the Birmenstorf Member with a thickness of only 7 cm. This bed with parts of siliceous sponges, few iron-ooids and with mature glauconite pellets floating in a matrix of lime mud was figured by Gygi (1969a, pl. 2:4), a longitudinally crosscut and polished surface of the drill core Gy 648. Ammonites of the Densiplicatum Subchron (Gygi & Marchand, 1982, pl. 12:3) and the index of the Antecedens Subchron (Gygi, 2001, fig. 62c) were found in this condensed, regional marker bed in excavation RG 208 (bed no. 10) on Brunnrain near Ueken, Canton Aargau. The top of the Spatkalk Member, number 25 in section RG 226 near Veltheim, indicates a water depth of about zero. A depth of deposition of about 100 m must be concluded from the iron-ooids and the mature glauconite pellets that both occur within the condensed marker bed no. 30 of section RG 226 at the base of the Birmenstorf Member. The vertical distance between the top of the Spatkalk Member (Early Bathonian) and the base of the Birmenstorf Member (base of the Middle Oxfordian) can be read to be less than 30 cm in section RG 226 from figure 2 in Mangold & Gygi (1997). Sedimentation amounted to less than 30 cm, and there was mostly nondeposition at this locality during about ten million years. During this time, water depth increased from 0 to about 100 m. Succession 1 is represented between Veltheim and Oberehrendingen in Canton Aargau only by the Birmenstorf Member.
Succession 1 in northwestern Switzerland was sedimented at a greater rate than the rate of net relative sea-level rise. Sedimentation began at a depth estimated at 70 m (see below), and the water depth diminished until the shallow epicontinental basin was filled with sediments to sea level at the end of deposition of the succession (Gygi, 1999, fig. 1).
The interplay of endogenic and exogenic (mainly isostatic) subsidence with a long-term, net eustatic sea-level rise as it was estimated by Gygi (1986, fig. 4) can be read from figure 187. Rapid, short-term relative sea-level rises are documented by Gygi (1986, fig. 5) in the St-Ursanne Formation and in figure 181 represented here of the upper Günsberg Formation. Relative sea-level falls are indicated by supratidal facies above sediments from shallow marine water (fig. 176, Waldenburg, and fig. 175, Balsthal).

8.1.6 Shallowing-upward and deepening-upward successions

In an epicontinental sea as it existed at the beginning of the Late Jurassic in northern Switzerland, the normal process of sedimentation is that the marginal, proximal part of the basin is filled in by sediments first. This is exemplified by succession 1 in northwestern Switzerland (fig. 187 A–B). Succession 1 is shallowing-upward in this area, because the average rate of sedimentation was greater than the mean rate of relative sea-level rise. The same, this is to say the coeval succession is deepening-upward in Canton Schaffhausen (fig. 187A–B) where relative sea-level rise greatly exceeded the minimal sedimentation rate or nondeposition, respectively.
A deepening-upward succession results for instance when a carbonate platform drowns. Evidence of the drowning of the Early Bathonian carbonate platform of the Spatkalk Member in Canton Aargau was given above. Later, at the end of the Early Callovian, the carbonate platform of the Dalle nacrée Member drowned in northwestern Switzerland. Gygi (2000a, pl. 22) documented this with his section RG 307 in the quarry La Charuque near Péry, Canton Bern. A minimal sedimentation rate and nondeposition during a long time of relative sea-level rise led to the drowning of the platforms. Succession 3 in Canton Aargau is pure calcareous mud that was sedimented mostly at a normal rate during a time when the depth of the water above the sediment increased. Evidence of this is given below. This is a case of a deepening-upward succession that was sedimented mostly at a normal rate. Rates of sedimentation are quantified in chapter 9.14 below.

8.2 The Rhodano-Swabian basin of northern Switzerland at the beginning of the Late Jurassic

8.2.1 Canton Schaffhausen

There was nondeposition at the time boundary between the Middle and Late Jurassic in Canton Schaffhausen. The sediments below and above the boundary were investigated in excavation RG 81b near Gächlingen and in the excavations RG 80, 207 and 212 near Siblingen (Gygi, 1977, pl. 11). Below the boundary is the iron-oolitic Herznach Formation, and above is the glauconitic Glaukonitsandmergel Bed. The age of the uppermost Herznach Formation could be established in excavation RG 81b with the ammonites *Erymnoceras* sp. and *Reineckeia* sp. to be Middle Callovian. *Cardioceras (Cardioceras) cordatum* (Sowerby) J 23027 was found in the Glaukonitsandmergel Bed, bed no. 14a of excavation RG 207 near Siblingen. This is the index of the Cordatum Subchron and was figured by Gygi & Marchand (1982, pl. 10:1). The ammonites document the existence of a major hiatus between the top of the Herznach Formation and the base of the Glaukonitsandmergel Bed in Canton Schaffhausen. Ammonites prevail in the macrofauna both of the Herznach Formation below and of the Glaukonitsandmergel Bed above. This is evidence that the hiatus evolved in relatively deep water.
Only a few kilometers north of the northern border of Canton Schaffhausen was an opencut iron mine at the foot of Stoberg hill near Blumberg, southern Germany. There, the iron-oolitic Herznach Formation was mined for iron in a long trench during World War II. Zeiss (1955, fig. 31) measured and published the section. He found no indication of a hiatus between the iron-oolitic Herznach Formation and the glauconitic Glaukonitsandmergel Bed. In this section that is now covered by land fill, the vertical transition from iron-oolitic facies below to glauconitic facies above is in the Lamberti Bed of the latest Callovian. This bed is at most 5 cm thick and includes both iron ooids and glauconite pellets.

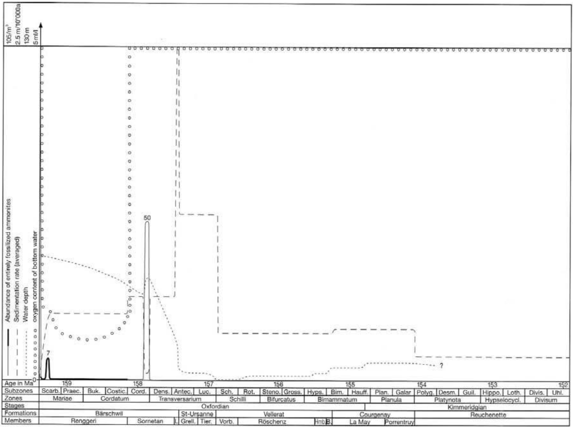


Fig. 185. Variables that influenced sedimentation and the abundance of well-preserved ammonites during the Late Jurassic in northwestern Switzerland.

The scales of the curves are given in the upper left corner of the figure. The curve of ammonite abundance is a bold line where ammonites are fossilized as steinkerns of iron sulfide (a variable intergrowth of pyrite and marcasite). The numerical time scale is adopted from Gradstein et al. (1995). This differs only slightly from the time scale that was later published by Hardenbol et al. (1998, chart no. 7) in de Graciansky et al. (1998).
Adapted from fig. 1 in Gygi (1999).

8.2.2 Canton Aargau and eastern Canton Solothurn

Sedimentation began in Canton Aargau and in eastern Canton Solothurn at the onset of the Late Jurassic at a very low rate. This is iron oolite of the upper Herznach Formation that could be dated with a number of ammonites found in sections near Herznach and near Gansingen. The ammonites are of the Scarburgense Subchron and were figured by Gygi & Marchand (1982). Deposition of iron oolite of the upper Herznach Formation in Early Oxfordian time in Canton Aargau was very slow and intermittent (Gygi, 1981, fig. 2). The total thickness amounted to a few decimeters at most. Formation of pure iron oolite ceased at the end of the Cordatum Subchron of the Cordatum Chron when the Schellenbrücke Bed was laid down. The whole Herznach Formation was found to be laterally discontinuous by Mangold & Gygi (1997). These authors stated that, with the exception of small lenses, there was nondeposition from the Late Bathonian to the beginning of the Middle Oxfordian in the area between Auenstein (section RG 37, Gygi, 1969, pl. 17, and RG 226, Gygi, 1973, fig. 3) and Oberehrendingen (sections RG 51a and b, Gygi, 1977, pl. 11). The Wildegg Formation above begins with a thin, but continuous marker bed at the base of the Birmenstorf Member. The thickness of the bed is nowhere more than 10 cm. This is bed no. 10 of section RG 208 near Ueken or bed no. 8 of section RG 210 near Gansingen as figured by Gygi & Marchand (1982, fig. 2). The bed is condensed and was laid down during the Densiplicatum and the Antecedens Subchron of the Transversarium Chron (Gygi, 2001, fig. 1). The Densiplicatum Subchron is documented by *Cardioceras (Subvertebriceras)* aff. *zenaidae* Ilovaisky in Arkell J 27212 as figured by Gygi & Marchand (1982, pl. 12:3). *Perisphinctes (Dichotomosphinctes) antecedens* Salfeld J 23168, the index of the Antecedens Subchron, was found in the same bed of excavation RG 208. The specimen was figured by Gygi (2001, fig. 62c).
Both iron ooids and mature glauconite pellets occur in the condensed bed at the base of the Birmenstorf Member. Only

glauconite is to be found in the uncondensed facies of the Birmenstorf Member above the marker bed. The time of vertical transition from iron-ooid to glauconite formation can then be assumed to be the end of the Densiplicatum Chron in Canton Aargau, much later than near Blumberg. This indicates that water depth at the beginning of the Oxfordian in Canton Aargau was less than near Blumberg (fig. 187A). A considerable relative sea-level rise must then have taken place at a time when sediments with a thickness of less than 1 m were laid down in Canton Aargau from the beginning of the Late Jurassic to the end of the Densiplicatum Subchron. As a consequence, water depth increased from the beginning of the Oxfordian, and accretion of iron ooids changed to glauconite formation early in the Middle Oxfordian in Canton Aargau. This was when water depth had increased in Canton Aargau to what it was near Blumberg at the beginning of the Oxfordian, this is to say to at least 100 m, too deep for iron-ooid accretion.

8.2.3 Section RG 307 near Péry, Canton Bern

Deposition of sediments of the Late Jurassic began near Péry with a thin bed of brown, iron-oolitic marl clay. The bed is no. 20 of section RG 307, and *Cardioceras (Scarburgiceras)* cf. *scarburgense* J 30717 was found in it (Gygi, 1990b, fig. 4). The distal, blue-gray marl clay of the Renggeri Member above is only 3.30 m thick and includes small ammonites of the Bukowskii Subchron that are preserved as casts of iron sulfide (Gygi, 1990b, pl. 6:3). A major hiatus exists between the top of the Renggeri Member and the base of the Pichoux Formation above. The lowermost bed of the Pichoux Formation is a micritic limestone with a thickness of 0.8 m that includes siliceous sponges. Large, mature pellets of glauconite are quite common in the bed. Among the ammonites found in this bed is *Perisphinctes (Dichotomosphinctes) antecedens* Salfeld J 27994 that was figured by Gygi (1990b, pl. 5:4). Consequently, the water depth at the beginning of the Late Jurassic was near Péry shallow enough that iron-ooids could be accreted. Sedimentation amounted to only 3.5 m during the Early Oxfordian and was apparently less than the relative sea-level rise that must have occurred in this time span. The increase in water depth since the beginning of the Late Jurassic was sufficient to stop iron-ooid accretion and to replace it by formation of large, mature glauconite pellets during the Antecedens Subchron.

The hiatus between the top of the Renggeri Member and the base of the Pichoux Formation represents the time of about four subchrons (Bukowskii to Densiplicatum Subchron, see fig. 185). The hiatus evolved in the deep subtidal zone. Bolliger & Burri (1970, fig. 30) thought that the hiatus was the result of emersion (exposure), and Allenbach (2001:269) agreed with that. Subaerial exposure between deposition of the Renggeri Member and the Pichoux Formation in this section can be ruled out, because ammonites prevail in both units, and because there are fully evolved glauconite pellets at the base of the Pichoux Formation that indicate a depth of deposition greater than 100 m (see above). Nondeposition began near Péry later than in Canton Schaffhausen and ended later. The two hiatuses must therefore have been caused by different conditions.

8.2.4 Northwestern Switzerland

Ammonites are abundant in this region only in the uppermost Herznach Formation and in the lowermost Renggeri Member. Nevertheless, sedimentation during the Oxfordian and Early Kimmeridgian in northwestern Switzerland is of interest, because it can be proved that during this time span, the epicontinental basin was entirely filled with sediments up to sea-level several times, and because even terrestrial facies occur. Meanwhile, the adjacent epicontinental basin was relatively deep and remained to be so troughout the investigated lapse of time (fig. 187A–D).

It can be deduced from the great number of detailed sections that were measured by Gygi (2000a, fig. 1) in northern Switzerland, that the basement subsided isostatically unde the load of sediments, and that the amount of isostatic subsidence varied from region to region when depocentres shiftec with time (fig. 187B–C). It is evident from the depositional history from the beginning of the Late Jurassic to Early Antecedens time between Canton Schaffhausen, Canton Aargau and Péry in Canton Bern, that a relative sea-level rise then oc curred in the whole area.

The earliest sediment of the Late Jurassic in northwester Switzerland is a thin, but widespread bed of brown, ferriferou marl clay with iron ooids and a thickness not exceeding 30 cm This is the uppermost bed of the Herznach Formation. Th bed seems to be uninterrupted between Liesberg and Péry an is dated with ammonites to be of the Scarburgense Subchro of the Mariae Chron (Gygi, 1990b, fig. 4). Ammonites preva in the macrofauna of this bed. The ammonite fauna is divers This is evidence that the uppermost part of the Herznach Fo mation in northwestern Switzerland is a sediment from th deeper subtidal zone in an open marine environment. Th presence of iron ooids sets an upper limit to water depth: Gy (1981:244, 248) concluded that about 100 m is the greate depth at which iron ooids could be accreted when being roll by episodic, oscillating currents during particularly stro storms at the surface of muddy sediment.

8.2.5 Water depth at the beginning of the Lat Jurassic in northern Switzerland

The water depth at the beginning of the Late Jurassic in nort western Switzerland can only be estimated. 100 m were co cluded to be the depth at this time near Blumberg, southe Germany, when accretion of iron-ooids there changed to f mation of glauconite pellets. The vertical transition from ir ooid accretion to formation of glauconite pellets occurred al in Canton Aargau and in eastern Canton Solothurn, m probably at the same depth of 100 m like near Blumberg, b later, at the end of the Densiplicatum Subchron. The tran tion occurred in Canton Aargau six ammonite subchrons la than near Blumberg. Water depth at the beginning of the L Jurassic in Canton Aargau and in eastern Canton Soloth must then have been less than it was at that time near Blu berg and in Canton Schaffhausen. Consequently, a step ex ed at the beginning of the Late Jurassic on the seafloor tween Canton Schaffhausen and Canton Aargau as represented in figure 187A. The step on the sea bottom tween the shallower water in Canton Aargau and the mark ly deeper water in Canton Schaffhausen at the beginning of the Late Jurassic is about where the margin of the carbonate platform of the Spatkalk Member was in Early Bathonian time (Gygi, 1986, fig. 1). This platform margin seems to have acted as a template of submarine topography at the onset of the Late Jurassic between Canton Aargau and Canton Schaffhausen, because there was little sedimentation in that region from the end of the Early Bathonian to the beginning of the Late Jurassic.

A similar step probably existed at the end of the Early Callovian at the margin of the Dalle nacrée carbonate platform (Gygi, 1986, fig. 1). The margin of the subsequent carbonate platform, the St-Ursanne Formation, is incongruent with the margin of the Dalle nacrée platform (Gygi, 1986, fig. 1). There is no way to quantify the difference in water depth that was caused by the step between Canton Schaffhausen and Canton Aargau at the beginning of the Late Jurassic. The difference must have been substantial, because it led to the lateral facies transition from the iron-oolitic Schellenbrücke Bed in Canton Aargau to the glauconitic Glaukonitsandmergel Bed in Canton Schaffhausen at the end of the Cordatum Subchron.

8.3 Succession 1: Bärschwil and St-Ursanne Formation and time equivalents

8.3.1 Vertical facies succession in succession 1 in northwestern Switzerland

8.3.1.1 Uppermost Herznach Formation

The rate of sedimentation of argillaceous mud was very low at the beginning of the Late Jurassic in northwestern Switzerland. This and the relatively shallow water depth that was of the order of 70 m (see below) made *in situ* accretion of some iron ooids possible. The uppermost, Oxfordian part of the Herznach Formation is only two to three decimeters thick in this region. The gray-brown colour of the matrix of the sediment indicates that oxygenation of the bottom water was normal. The oxygen content of the water can be estimated at about five milliliters per liter according to Gygi (1999:130).

8.3.1.2 Bärschwil Formation

8.3.1.2.1 Renggeri Member

The lower boundary of the Renggeri Member is above the uppermost iron ooids of the Herznach Formation. There, the colour of the clayey marl changes abruptly from gray-brown to blue-gray. This change occurred when the rate of sedimentation of argillaceous mud increased and became too great for iron-ooid accretion at the depth of about 70 m. The Renggeri marl clay is massive. Concomitant with the growing rate of supply of terrigenous mud must have been the advent of more nutrients from land. This led to an increase of primary productivity in plankton. The settling dead plankton consumed dissolved oxygen in the water. This caused a sharp drop in the oxygen content of the bottom water in the Scarburgense Subchron (fig. 175). The clayey marl of the lower Renggeri Member is burrowed (Gygi, 2000a, fig. 7). The burrows are filled with iron sulfide. The diameter of the burrows is seldom more than 1 mm. According to Savrda et al. (1984:1184), this documents a strong reduction of the oxygen content of the bottom water. A minimally aerobic to dysaerobic environment must be concluded following Brett & Baird (1986, fig. 11 and p. 217). An oxygen content of the water above the sediment surface of the order of one milliliter per liter is probable to conclude from the classification of trace fossils by Ekdale & Mason (1988:720).

Ammonites are not rare in the lower Renggeri Member. They are preserved as casts of iron sulfide (pyrite, marcasite or an intergrowth of the two minerals). The diameter of the ammonite casts does not exceed about 3 cm in the clay pit of Andil near Liesberg, Canton Basel-Landschaft (section RG 280, Gygi, 1990b, fig. 3), but most ammonites are smaller. Larger specimens are very rare near Liesberg and occur in the upper Renggeri Member. Large ammonite casts of iron sulfide were also found near Saulcy, Canton Jura (oral communication by P. Borer, a private collector). Most of the small ammonites that occur near Liesberg are preserved with part of the body chamber, and some of these are adult and complete. Consequently, these ammonites are dwarfs according to the classification of size given by Gygi (2001:12). The iron sulfide of the ammonite casts was formed in the course of early diagenesis, because the body chamber of larger specimens, if it contains no iron sulfide, is sometimes flattened by subsequent compaction of the clayey marl in the body chamber. The inner whorls with a high content of iron sulfide are not flattened.

Ammonites prevail in the macrofauna of the Renggeri Member. This and the rich assemblage of palynomorphs found by Berger (1986) in the lowermost part of the Renggeri Member, and by Ghasemi et al. (1999) in the whole Renggeri Member, is an indication that the water was relatively deep. Ghasemi et al. (1999) found no dinoflagellates in the Bure Member that is a similar sediment of mainly blue-gray argillaceous mud, but was deposited in very shallow water (fig. 173).

The calcareous nannoplankton found by Grün & Zweili (1980) in the lowermost Renggeri Member is also an indication that sedimentation of the Renggeri Member began in relatively deep water. The water directly above the sediment surface cannot have been anoxic because of the burrowing of the sediment and because there are some benthic organisms like small bivalves and brachiopods in the macrofauna. The thickness of the Scarburgense Subzone near Liesberg is only about 3.5 m (Gygi, 1990b, fig. 3). The thickness of the Praecordatum Subzone above is much greater and indicates that the sedimentation rate augmented with time (fig. 185), provided that the subzones were of equal duration. It is probably because of the higher rate of sedimentation from the later Scarburgense Subchron on that ammonites are uncommon in the middle and in the upper Renggeri Member (Gygi, 1999:136). A varying oxygenation of the bottom water was probably not the cause of the change in ammonite abundance, because the ammonites are small casts of iron sulfide from base to top of the member with the exception of very few large specimens close to the top near Liesberg.

The low oxygen content of the bottom water during deposition of the Renggeri Member cannot be the consequence of restriction of the basin. There is no indication of the existence of a threshold in eastern Canton Aargau that was inferred by Norris & Hallam (1995) and again by Allenbach (2002, fig.

15b). Such a threshold probably *did* exist, but it was further south above what is now the Aar Massif in the Alps (see below). Sedimentation of the Renggeri Member began at a water depth that was of the same order or rather somewhat less than that in eastern Canton Solothurn and in Canton Aargau at this time (fig. 187A). The member was certainly not sedimented into a trough as Allenbach (2001) thought (see below). On the contrary, the argillaceous mud of the member was part of a submarine bank, this is to say of a positive physiographic structure. The Renggeri Member is the lowest part of the shallowing-upward succession 1 that filled the epicontinental basin entirely to sea level in northwestern Switzerland. Evidence of this is the intertidal stromatolite in the Vorbourg Member represented in figure 178.

It is exogenic, mainly isostatic lithosphere subsidence under the sediment load of the Bärschwil Formation that produced a trough-like structure in the basement (fig. 187B). This trough was the effect, not the cause of argillaceous mud accumulation. Evidence of this is given below. The low oxygen content of the bottom water evolved in an open marine, shallow epicontinental sea with water that was normally aerated near sea level. Low oxygenation was probably brought about by an enhanced rate of primary production (Thomson et al., 1999 in Krom et al., 2002:73) as is indicated by the rich and diverse assemblage of palynomorphs in the Renggeri Member that was recorded by Ghasemi et al. (1999). In such an environment, low oxygenation of the bottom water could only evolve when the water was almost stagnant. This peculiar facies occurred at the same time in England (Arkell, 1939) and at Mt. Hermon in the borderland between Israel and Syria (Noetling, 1887, Haas, 1955). The rich palynomorph assemblage in the Renggeri Member is evidence that the oxygenation of the upper part of the water column was normal. Conversely, the dwarf size of the ammonites in the member indicates that the ammonites lived permanently in the poorly oxygenated water just above the bottom.

8.3.1.2.2 Sornetan Member

The Sornetan Member is a blue-gray marl-clay with bands of ellipsoidal, calcareous nodules (Gygi, 2000a, fig. 31) and with some continuous beds of marly limestone, that were both studied in many thin sections. The nodules were called "chailles" by earlier authors. This led to the misleading name of the member "Terrain à chailles". A chaille is a nodule of flint. According to Enay (1966), the correct French name for the tough, calcareous nodules in the member is sphérite. The base of the member is where the first nodule band appears above the Renggeri Member (Gygi, 2000a, fig. 23). Macrofossils are normally uncommon in the member. Calcareous casts of ammonites with a normal size prevail in the macrofauna of the lower part of the member and indicate normal oxygenation of the bottom water. The change from low oxygenation of the bottom water in the Renggeri Member below to normal oxygenation of the bottom water in the Sornetan Member above probably occurred when the sediment surface was raised by continuing sedimentation at a rate that was greater than the rate of relative sea-level rise. Bivalves of the genus *Pholadomya* are the main representatives of the macrofauna in the upper Sornetan Member. This too is interpreted to be the effect of shoaling of the water by continuing infilling of the proximal part of the basin.

Up to 10% of goethitic iron ooids occur in a muddy matrix m below the top of the Sornetan Member in bed no. 3 of t unpublished section RG 456, an exploration well drilled f the Transjurane superhighway near Bure, Canton Jura (ro sample Gy 7568, thin section Gy 7563). The iron ooids are e bedded in a limey marl that was sedimented at a depth that c be estimated at somewhat more than 20 m (see below).

A band of calcareous nodules with a thickness of 10–20 c that was found in several sections in the distal part of t member deserves special attention. The bed with nodules cludes a rich macrofauna in which ammonites prevail. T fossil bed is about in the middle of the member. It was d cerned for the first time by Gygi & Persoz (1986, table 2). T macrofossils occur only in the calcareous nodules. The gr majority of the ammonites is of the genus *Cardioceras* (G & Marchand, 1993, fig. 4, pl. 1–3) that were dated at the C datum Subchron of the Cordatum Chron. The unusual co centration of macrofossils in this bed and the fact that a monites prevail, indicate that the bed was deposited a strongly reduced sedimentation rate in relatively deep wa (Gygi, 1999:135). The depth of deposition of the fossil b with mainly ammonites is estimated to have been, based evidence given below, between 30 and 40 m.

8.3.1.2.3 Liesberg Member

The Liesberg Member in the clay pit at the type locality Hir Chestel near Liesberg, Canton Basel-Landschaft (section 306, pl. 31 in Gygi, 2000a), is a blue-gray marl with band carbonate nodules with an irregular shape. The nodules di in this respect from the regularly ellipsoidal nodules in Sornetan Member below. Two successive, continuous bed marly limestone are about in the middle of the Liesberg M ber in this section (beds no. 102 and 104). A. Coe found a la perisphinctid ammonite 4 m above the base of the membe bed no. 101 of section RG 306. This is unusual, because the only ammonite the author knows of that was found *in* in the member at the type locality. Other macrofossils are abundant. As much as 30% of the rock volume are herma ic corals that are mainly dish-shaped microsolenids in the er part of the member (Insalaco, 1996, fig. 6, 14B, Gygi, 20 fig. 32). In the upper part of the member, ellipsoidal c colonies with the massive shape of a bread loaf become creasingly common. Associated with the corals are abun echinoids, crinoids, bivalves and brachiopods. Both macrofossils and the calcareous nodules are partly chert in the Liesberg Member.

An oolitic iron ore with a reported thickness of 1–8 m an iron content of less than 20% occurs in the equivalent o uppermost Liesberg Member between Chamesol and M techeroux, two villages that are about 20 km south of M béliard, France. The ore deposit is just west of the Swiss der, in the southeastern corner of the Carte géolog 1:50 000 Montbéliard XXXV-22 (1973). According to "note explicative", page 7 of the geological map, the iro was mined until after 1900. Directly above the ore is equivalent of the St-Ursanne Formation, the sediment carbonate platform from a water depth of less than 10 m. water depth at which the iron ooids were accreted can t fore be estimated to have been about 10 m.

The palaeoecology of the Liesberg Member is interestin cause of the great abundance of hermatypic corals that in an environment where argillaceous mud could settle down at the high rate of up to 2.5 m per 10000 years (fig. 185). Sedimentation of the member began at a depth that can be estimated at only about 20 m and ended at a depth of the order of 10 m. The water depth, when the top of the Liesberg Member at the type locality was laid down, can be estimated from the oncolite in the lowermost St-Ursanne Formation above that grades upward into calcareous oolite (Gygi, 2000a, pl. 31). Calcareous oolite is indicative of a water depth of less than 10 m (see text above and fig. 180). Dish-shaped hermatypic corals of the Recent are, according to Graus & McIntyre (1976), an adaptation to low average illumination. They are normally abundant in deep fore-reef environments. They can survive at a depth of as much as 160 m in the clear water of the Red Sea (Kaise et al., 1993, in Insalaco, 1996:186). Platy hermatypic corals are therefore thought to be indicative of an environment with a low level of illumination. The author found delicate, platy colonies of the coral *Agaricia fragilis* Lamarck in the shade below an overhang of Pleistocene limestone more than 4 m wide directly below low tide level on the coast of Harrington Sound, Bermuda, at a depth of less than 2 m (Gygi, 1969b, fig. 17 d–e). The overhang is the effect of bioerosion by the boring sponge *Cliona lampa* as was studied by Neumann (1966, fig. 3).

Presence of platy coral colonies in an argillaceous mudstone like the Liesberg Member or a in a lime mudstone as for instance the Olten Member (Gygi, 2000a, fig. 12) can therefore not be taken at first glance as evidence of deep water. Predominance of platy coral colonies in the Liesberg Member may reflect a reduced depth of light penetration that was caused by much sediment in suspension in the turbid water that must be assumed because of the high sedimentation rate that was concluded by Gygi (1999, fig. 2).

According to Zlatarski & Martinez Estalella (1982:395), turbidity of the water does not inhibit growth of hermatypic corals at shallow depth, even when turbidity is permanent.

However, turbidity of the water cannot be the only controlling factor for the mass occurrence of platy coral colonies in shallow water as in the Liesberg Member. Platy corals are also abundant in a biostrome with a groundmass that was originally lime mud in the Günsberg Formation north of Grandval, Canton Bern (Ziegler, 1962, fig. 7, pl. I/8a, bed no. 5). The corals were found again by the author (polished slab Gy 4759 from bed no. 27 in the unpublished section RG 410). Platy corals are known for a long time to occur in the middle of the Olten Member (bed no. 35 of section RG 21, quarry on Mt. Born near Olten, Gygi, 1969a, pl. 18, and Gygi, 2000a, fig. 12). Platy colonies in this bed can be as thick as 10 cm and up to several meters wide (Gygi, 1969a:75). They were assumed to be hydrozoans by Gygi (1969a) following an opinion given orally by E. Flügel during a visit in the quarry on Mt. Born. Bed no. 35 of this section was probably deposited at about the same shallow depth as the Liesberg Member. But turbidity of the water out of which the lime mud of the Olten Member settled must have been a fraction of that of the water from which the argillaceous mud of the Liesberg Member was sedimented, if water turbidity can indeed be concluded from the sedimentation rates as were calculated by Gygi (1999, fig. 1–2, see also Dupraz, 1999).

8.3.1.3 St-Ursanne Formation

The base of the St-Ursanne Formation is a vertical change from marl to limestone. The change can be a clear-cut boundary like in section RG 306 near Liesberg between beds no. 106 and 107 (Gygi, 2000a, pl. 31), or it can be transitional like in the landslide west of Vögeli farm southwest of Bärschwil (Gygi, 2000a, pl. 34, section RG 399). The lower part of the formation is a coral biostrome with crinoids and, near St-Ursanne or Bärschwil, with oncoids (algal nodules). The abundance of oncoids can grow near St-Ursanne to oncolite concentration. Oncolite is a rock with a high content of oncoids (algal nodules that are primarily hard). This local facies was called Caquerelle pisolite by Ziegler (1962:18). The facies must be kept separate from the younger Caquerelle Member of Rollier and subsequent authors that was recommended to be called Buix Member by Gygi (2000a:56) in order to avoid confusion. Pümpin (1965, fig. 6–8) gave thin section photographs of the oncolite. The oncolite was again recorded in 1981 along a new forest road at the locality Côte du Frêne on the territory of the village Asuel, Canton Jura, in the unpublished section RG 338 northeast of St-Ursanne. Examples of the oncolite are the polished slabs Gy 3898 from bed no. 89 and Gy 3899 from bed no. 90 of section RG 338. At Côte du Frêne, the oncolitic beds are part of the upper Delémont Member.

Individual coral bioherms fringe the margin of the carbonate platform of the lower St-Ursanne Formation (fig. 173). On the inner platform, the coral biostrome of the lower St-Ursanne Formation grades upward into a belt only 4–8 km wide of pure calcareous oolite in the upper Delémont Member. Formation of this oolite sand shoal began at a distance of about 10 km inward from the fringe of coral bioherms growing at the platform margin. Then the surface of the coral biostrome of the distal Grellingen Member was raised by sedimentation of lime mud to a depth shallow enough for the accretion of calcareous ooids. At that time, the oolite shoal of the Delémont Member could prograde towards the distal part of the platform. This initiated formation of the oolitic Tiergarten Member close to the platform margin, where the rate of formation of calcareous ooid sand could keep up with the rapid eustatic sea-level rise that occurred at that time (see below).

Recent marine, calcareous ooids are typically accreted near the margin of carbonate platforms at a bathymetric range from the lower intertidal zone down to a maximum depth of less than 10 m (see text above and fig. 180). The ooids have a diameter of up to 2 mm. Examples of the Late Jurassic were figured by Gygi (1969a, pl. 8:32–33). No evidence was found in oolites of the carbonate platforms of the Late Jurassic in northern Switzerland that calcareous ooids were finally embedded far from where they were accreted. The thickness of the tidal delta in the uppermost Günsberg Formation near Péry (fig. 181, section RG 307, beds no. 193–195 of pl. 22 in Gygi, 2000a) documents that the delta issued into water that was only 5.7 m deep (see above). The representation of beds no. 193–195 in plate 22 by Gygi (2000a) is at variance with what can be seen in the photograph of figure 181.

The normal vertical facies succession with diminishing water depth is from hermatypic corals below to calcareous oolite above and then to supratidal facies. The corresponding lateral facies succession in the Recent can be read from figure 179. Deposition of the oolitic Delémont Member on the inner platform of the lower St-Ursanne Formation ended near St-Ursanne with an uneven surface that must have been very near or even within the intertidal zone. This surface is well visible in the quarry of the former lime works near the railway station of St-Ursanne.

The conspicuous, uneven surface at the top of the lower St-Ursanne Formation in the type section near St-Ursanne is the base of coral bioherms (Gygi, 1986, fig. 5) that can be as high as about 20 m. Up to 50% of the volume of these bioherms are massive or thickly branching coral colonies in the quarry near St-Ursanne (unpublished section RG 336, unit no. 18). Between the corals is ruditic, unsorted biogenic detritus in the marginal part of the bioherms, and micrite in the bioherm core. The bioherms were probably rigid, wave-resistant structures and were therefore true reefs. Pümpin (1965, fig. 64) found that the elevation of the reefs above the surrounding sediment was at all times slight, mainly towards the end of reef growth. The sediment between the reefs is white, porous and friable lime mudstone with a carbonate content that can exceed 99%. This unbedded, very pure limestone is the typical facies of the Buix Member of the upper St-Ursanne Formation (Gygi, 2000a:56). The porous, inter-reef sediment is much less resistant to weathering than the well-cemented reefs. This is why the reef photographed by Gygi (1986, fig. 5) appears as a structure with high, steep flanks unlike the reef as was drawn by Pümpin (1965, fig. 64). Pümpin found perisphinctid ammonites in the inter-reef sediment of the Buix Member that were figured by Gygi (1995, fig. 4 and 14). The Buix Member grades laterally towards the platform margin into the oolitic Tiergarten Member (fig. 173). Small coral reef knolls were found within the oolite of the Tiergarten Member near Grellingen, Canton Basel-Landschaft. Recent counterparts of these may be the small coral reefs growing in the tidal channel that is visible in figure 179 between an active oolite shoal on the left, and an island of the Joulters Cays on the right, north of Andros Island, Bahamas. The channel was estimated to be about 4 m deep during a dive by the author. The Tiergarten Member rimmed the lagoon in which the Buix Member was deposited. A fringe of coral bioherms then grew at the platform margin (fig. 173). Above the reefs of the Buix Member of the inner platform is the peritidal, bedded micritic limestone of the Vorbourg Member (Gygi, 1986, fig. 5) that belongs to the lower Vellerat Formation.

The environmental interpretation of the facies pattern in the St-Ursanne Formation is that a rapid, eustatic increase of water depth ended the accretion of calcareous ooids on the narrow ooid sand shoal of the Delémont Member on the inner platform. The rate of sea-level rise must then have become greater than the rate of ooid sand production in the platform interior, until the water became too deep for accretion of calcareous ooids. Water depth therefore increased above the inner platform sufficiently to allow for growth of luxuriant lagoon reefs. The vertical facies transition from ooid accretion in the Delémont Member below to growth of coral reefs and deposition of inter-reefal lime mud of the Buix Member above is inverse. Gygi (1986:467) interpreted this transition to be the effect of a rapid and substantial eustatic sea-level rise, because he could quote coeval transgressions that other authors had documented from eastern France and southern England. Another example of this was published since by Dugué et al. (1998, fig. 3) from northern France. It cannot be established how deep the lagoon was near St-Ursanne at the onset of reef growth. The depth must have been of the order of 10 r enough to prevent further accretion of calcareous ooids. Tl lagoon was deep enough that ammonites could live in it least temporally. The ammonites known from the lagoon St-Ursanne are all perisphinctids (Gygi, 1995, fig. 4, 6, 14–15 Then the lagoon was progressively filled in with lime mu This reduced water circulation that was the condition to tl survival of coral reefs, and the reefs eventually suffocated the mud. Mud depositon continued until the lagoon was cor pletely filled at the end of the Transversarium Chron when t sediment surface was raised to the intertidal zone. This can concluded from the intertidal stromatolite that was found the lower Vorbourg Member of section RG 306 near Liesbe (Gygi, 2000a, pl. 31, bed no. 121a), and that is refigured he in figure 178. Formation of calcareous ooid sand could ke up with the rapid sea-level rise only near the platform marg in the Tiergarten Member, where the rate of carbonate preci itation was at a maximum.

8.3.2 Lateral facies succession in succession 1

The uniform facies of the thin deposits of iron oolite with macrofauna in which ammonites prevail at the beginning the Late Jurassic between northwestern Switzerland and ea ern Canton Aargau is indicative of a water depth in the de subtidal zone that did not vary substantially. The following cumulation of argillaceous mud with the configuration of widespread bank with a flat top, then of a carbonate platfo above the mud bank in northwestern Switzerland, produced shallowing-upward succession that filled in the basin to level. Loading of the lithosphere with the sediments of succ sion 1 caused the basement to subside. Subsidence was prol bly mainly isostatic and to a lesser degree the effect of co paction of older sediments below. A trough-like depression the basement was the effect (see chapter 9.17 and fig. 187 At the same time an ever increasing difference in water de evolved between northwestern Switzerland and eastern C ton Solothurn or Canton Aargau. This led towards the end deposition of succession 1 to the lateral transition from shallow-water facies of the upper St-Ursanne Formation w coral bioherms and calcareous oolite to the Birmenst Member with siliceous sponges and ammonites, that was posited in deeper water.

Gressly (1838–1841), following Merian (1821), correla what was then the Terrain à chailles (now: Sornetan Memb with the whole of the Wildegg Formation. He thought t what is now the Birmenstorf Member at the base of Wildegg Formation was older than the St-Ursanne Forr tion. Later he correlated the Birmenstorf Member corre with what is now the Pichoux Formation in the Court gc near Moutier (Gressly, 1864:103). In this gorge, the limest of the Pichoux Formation is intercalated between the relat ly thick, argillaceous Bärschwil Formation below and argillaceous Effingen Member above that is there several t of meters thick as was figured by Gygi (2000a, fig. 34). T photograph proves that the Bärschwil Formation, the Pich Formation and the Effingen Member can be present in str graphic order one above the other as is indicated in figure Gressly (1864) assigned in Court gorge both the Bärsch Formation and what is now the Effingen Member above to terrain à chailles". He regarded the pure limestone of the Pichoux Formation in Court gorge to be an intercalation in his 'terrain à chailles" and thought that the "terrain corallien ou auracien" (now: St-Ursanne Formation) was younger than he Pichoux Formation (Gressly, 1864:96).

The iron oolite of the uppermost Herznach Formation, the whole Renggeri Member and the lower half of the Sornetan Member of northwestern Switzerland have an average compacted thickness of about 80 m (fig. 173). This sediment stack thins to a few decimeters in eastern Canton Solothurn and in Canton Aargau where it is represented by the iron oolite of the upper Herznach Formation. Deposition of this thin, widespread unit with a macrofauna in which ammonites prevail began in Canton Aargau in the deep subtidal zone and ended when the water became deeper than about 100 m because of a minimal rate of sedimentation and a relative sea-level rise. The uppermost part of the Herznach Formation in Canton Aargau, the Schellenbrücke Bed, is in the proximal direction coeval with the fossil bed about in the middle of the distal part of the Sornetan Member. In the distal direction, the time equivalent of the Schellenbrücke Bed is the Glaukonitsandmergel Bed (Gygi et al., 1998, fig. 9). This is documented by numerous ammonites that were figured by Gygi & Marchand (1982) and by Gygi & Marchand (1993).

Gygi (1981) studied the mode of formation of the iron ooids of the Schellenbrücke Bed and concluded that they were accreted *in situ* in well-aerated water at a depth approaching 100 m (Gygi, 1981, fig. 4). There are iron ooids in the bed that are partly brown and partly green (Gygi, 1981:237). The iron ooids were evidently not transported from shallow water into the muddy sediment of the Schellenbrücke Bed (thin section Gy 2712 from bed no. 3 of section RG 32 at the type locality of the bed as figured by Gygi, 2000a, fig. 9). Norris & Hallam (1995:231) thought that the iron ooids in the uppermost Herznach Formation near Liesberg and Péry were "allochthonous, transported into the area of biomicritic deposition". Only an unidirectional current could cause such a transport. The muddy matrix would have been swept away in the process. Moreover, Gygi (1969a, pl. 3:8) documented that green iron ooids can be originally soft. The iron ooids would have been worn to annihilation when transported over a long distance by a current as envisaged by Norris & Hallam. Norris & Hallam (1995:229) studied a section of the Herznach Formation "in a trench in the woods near Mönthal", Canton Aargau. This can only be section RG 60 in the cleft of Eisengraben as represented in Gygi (1969a, pl. 17) or RG 210 and RG 230 in Gygi (1977, pl. 11, and Gygi, 2001, fig. 1). This outcrop is on the territory of the village of Gansingen, Canton Aargau. It is the reference section of the Transversarium Zone that was designated as such by Gygi (1977:517). Norris & Hallam (1995) paid special attention to nodules derived from the sandy limestone below the iron-oolitic bed and to nodules of iron oolite. Both kinds of nodules are encrusted with limonite and are embedded in the iron-oolitic Schellenbrücke Bed. Gygi had recorded these encrusted nodules in all of his sections of Eisengraben that were published since 1966. Norris & Hallam (1995:231) interpreted the nodules to be reworked concretions that were formed on a hypothetical "swell" at a lesser water depth than the coeval Renggeri Member and the lower Sornetan Member.

The sandy limestone in the nodules within the Schellenbrücke Bed of the Gansingen sections is identical with the sandy limestone of the bedded succession below the Schellenbrücke Bed. The succession of sandy limestone (beds no. 4–6 of section RG 210 = excavation 1 of pl. 11 in Gygi, 1977) is dated of the Early Callovian by the *Macrocephalites (Dolikephalites) gracilis* Spath J 27255 in the Museum of Natural History, Basel. The nodules of sandy limestone within the Schellenbrücke Bed of this section are certainly not concretions, but were rather the product of submarine corrosion (subsolution of Heim 1958:643). However, the nodules of iron oolite in the Schellenbrücke Bed could be concretions as was assumed by Norris & Hallam (1995:231) that were formed within marl. The marl may later have been winnowed and the isolated nodules then been encrusted with limonite as indicated by Gygi (1981, fig. 3).

There is no evidence of a swell in Canton Aargau at the beginning of the Oxfordian as was inferred by Norris & Hallam (1995:231). Both the sedimentology and the macrofauna of the earliest Oxfordian iron oolites in northwestern Switzerland and in Canton Aargau indicate that they were laid down at a similar and substantial water depth. The vertical transition from iron-ooid accretion to formation of glauconite pellets occurred near Gansingen (sections RG 60 and 210) and near Ueken (section RG 208) at the same time within the marker bed directly above the top of the Herznach Formation and at the base of the Birmenstorf Member. This is another indication of uniform depth. A swell was assumed to exist at this time by several authors further south above what is now the Aar Massif (reviewed by Gygi, 1992, fig. 2, Gygi, 2000a, fig. 64).

The iron ooids in the condensed bed at the base of the Birmenstorf Member in Canton Aargau cannot have been exported from the coeval iron-oolitic, shallow-water deposits of the upper Sornetan Member and of the upper Liesberg Member in the northwest (see above). In section RG 314 in the Pichoux gorge near Sornetan, Canton Bern, there are no iron ooids in the upper Sornetan Member, and the Liesberg Member was not sedimented at all in this section (Gygi, 2000a, pl. 21). Further in the distal direction, in section RG 307 near Péry, Canton Bern, nondeposition began during the Early Cordatum Chron and continued in the time interval represented by the upper Sornetan Member and the Liesberg Member (Gygi, 2000a, pl. 22).

A relative sea-level rise occurred during deposition of succession 1. Evidence of this is the fact that the vertical transition from iron-ooid accretion to formation of glauconite pellets, that was caused by increasing water depth, occurred in Canton Aargau much later than near Blumberg (see above). The average sedimentation rate of succession 1 in northwestern Switzerland was greater than the average rate of relative sea-level rise. As a consequence, the water depth diminished until this part of the basin was filled to sea level at the end of deposition of succession 1. Conversely, the average sedimentation rate of succession 1 in Canton Aargau and in Canton Schaffhausen was at the same time much less than the rate of relative sea-level rise. The total thickness of succession 1 in excavation RG 81b near Gächlingen in Canton Schaffhausen is only 0.5 m (see below and Gygi, 1977, pl. 11). The water depth therefore increased in the epicontinental basin of northeastern Switzerland during deposition of succession 1. This increase was further enhanced by the loading of the basin floor with the additional water brought about by the relative sea-level rise. Loading with water led to exogenic subsidence of the basement. The relative sea-level rise during deposition of succession 1 in northern Switzerland cannot be quantified. The initial water depth near Blumberg north of Schaffhausen at the beginning of the Late Jurassic was at least 100 m (see above and fig. 187A). The relative sea-level rise mentioned above caused the basement to subside. At the same time, sedimentation amounted to less than 1 m in Canton Schaffhausen. As a consequence, water depth increased in Canton Schaffhausen until the end of the Transversarium Chron to significantly more than 100 m (fig. 187B).

The thickness of succession 1 of less than 1 m in Canton Schaffhausen as stated above is deduced from the following facts: The author established the definitive order of his reference collection in the Museum of Natural History, Basel, in the summer of 2001. E. Glowniak (Warsaw) was visiting when the work was underway and discovered *Larcheria schilli* (Oppel) J 31141 among the material from section RG 276 near Holderbank, Canton Aargau, a specimen the author had lost out of sight. The ammonite was found near Holderbank and was donated to the author by the private collector D. Krüger in 1987. According to D. Krüger, the specimen was found in bed no. 39 of section RG 276 that was published by Gygi et al. (1979, fig. 3). The informations given by D. Krüger were checked by the author in several cases and were found to be reliable. Gygi (2001:8) reintroduced the Schilli Zone based on several specimens of *Larcheria schilli* (Oppel) that were found *in situ* in what is now bed no. 42 of section RG 276. These ammonites were figured by Gygi (2001, fig. 4), and the section was then designated to be the reference section of the Schilli Zone.

The consequence of this is that the base of the Schilli Zone in the reference section of the zone, RG 276 near Holderbank, Canton Aargau, has to be redefined to be the base of bed no. 39, not bed no. 42 as concluded by Gygi (2001:9). The age of the specimens of *Subdiscosphinctes (Aureimontanites) holderbankensis* Gygi that were found near Holderbank and near Oberehrendingen (Gygi, 2001, fig. 214–215) is then Early Schilli Chron, not Late Transversarium Chron as indicated by Gygi (2001) to be the age of the holotype. Therefore, it can be assumed that the age of *Subdiscosphinctes (Aureimontanites) holderbankensis* J 24747 from bed no. 11 of excavation RG 212 above the shooting range in Churz Tal near Siblingen, Canton Schaffhausen (Gygi, 1977, pl. 11, section 7), is also Early Schilli Chron. This would mean that the base of the Schilli Zone in Canton Schaffhausen and near Blumberg is where the succession begins to be glauconite-free, this is to say within bed no. 8 of section RG 80 near Siblingen, at the base of bed no. 16 in section RG 81b near Gächlingen, at the base of bed no. 5 in section RG 88 near Blumberg, and within bed no. 10 in section RG 212 near Siblingen. All these sections are represented in plate 11 by Gygi (1977). Succession 1 in this region is then indeed less than 1 m thick, and the question marks at the top of the Transversarium Zone of Canton Schaffhausen in figure 1 by Gygi (2001) can be deleted.

The stratigraphy of succession 1 in Canton Schaffhausen is represented in Gygi (1977, pl. 11) and in Gygi (2001, fig. 1). The succession begins with the Glaukonitsandmergel Bed that is above an important hiatus (see above). The Glaukonitsandmergel Bed is the time equivalent of the Schellenbrücke Bed in Canton Aargau. The thickness of the Glaukonitsandmergel Bed varies between 10 and 20 cm. The age is the Cordatum Subchron (see above).

The Mumienmergel Bed above the Glaukonitsandmergel Bed is a condensed bed with a thickness of only about 15 cm. It was laid down at a very low average rate during the Densiplicatum Subchron and the earlier part of the Antecedens Subchron (Gygi, 2001, fig. 230). This bed is interesting from the ecological point of view, because it was sedimented at a mean water depth exceeding 100 m, and, even though being a sediment from the deep subtidal zone, it includes large oncoids. To judge from the minimal sedimentation rate, the water must have been exceptionally clear, and the light intensity at the seafloor sufficient to allow for growth of phototrophic, encrusting microorganisms at this relatively great depth. The smallest oncoids have a diameter of about 3 cm and are nearspherical (Gygi et al., 1979, fig. 14a). Larger oncoids are ellipsoidal, and most of them have an ammonite as a core (op.cit., fig. 14b). The maximum diameter of ammonites with an oncolitic crust was found to be more than 30 cm. It can be concluded of partial geopetal infillings of lime mud in chambers between septa of the phragmocone of oncolitically encrusted ammonites that even the large ammonites have been overturned during fossilization (cross-cut oncoid Gy 7449 as figured by Gygi, 1992, fig. 36). This is evidence that the encrusted ammonite steinkerns are indeed large oncoids, not concretions. Overturning of calcareous oncoids the size of several decimeters that are embedded in argillaceous mud at a depth of more than 100 m by storm-induced currents can be ruled out. Recent hogfish are carnivorous (Böhlke & Chaplin, 1970:444) and were observed near coral reefs in the tropical West Atlantic to overturn large nodules of red algae in search of prey animals hiding at the underside of the nodules. Fish are then likely to have overturned the oncolitically encrusted ammonite steinkerns in the Mumienmergel Bed for the same purpose. The history of fossilization of the calcareous ammonite steinkerns with lime mud within the chambers of the phragmocone, must have been complicated, because the calcareous steinkerns are embedded in argillaceous mud. Moreover, a calcareous steinkern was found that was winnowed free of embedding mud after formation and then broken by an unknown process. The fragments remained close together. At a later stage the interspace, about 5 mm wide, between the fracture faces was filled with glauconitic lime mud that was indurated soon after. The fracture edges of the steinkern remained undamaged. Therefore, the infilling between the fractures could be prepared away and the ammonite fragment then glued so neatly that the fractures are now hardly visible (specimen J 24598 as figured by Gygi, 2001, fig. 50).

The Mumienmergel Bed that has an average thickness between 10 and 15 cm, was laid down during the Densiplicatum Subchron and the earlier part of the Antecedens Subchron. This is a time span of the order of 500 000 years, that is evidence of a minimal average sedimentation rate of the bed. On the other hand, a large ammonite shell can only be transformed into and survive as an underformed steinkern, if it is rapidly smothered with calcareous mud after death and decay of the animal within, when the shell comes to rest on the seafloor. Empty shells that are not embedded in protecting sediment soon after they settle on the bottom are prone to be destroyed by boring fungi or algae. This is what happened probably to most of the shells in the environment of the Mumienmerg

Bed where there must have been nondeposition most of the time.

The taphonomy of the similar Mumienkalk Bed that is above the Mumienmergel Bed and that was laid down in even somewhat deeper water was discussed in detail by Gygi in Gygi et al. (1979). Sedimentation of succession 1 ended in Canton Schaffhausen with deposition of a glauconitic marl that is only about 10 cm thick and that locally can pass laterally into limestone as is the case in bed no. 15 of excavation RG 81b near Gächlingen. This bed is represented in section number 6 in plate 11 of Gygi (1977).

Sedimentation of the St-Ursanne Formation ended when the basin was filled to sea-level in northwestern Switzerland. The coeval top of the Birmenstorf Member at the toe of the sloping Pichoux Formation at Günsberg, Canton Solothurn, and in Canton Aargau, can be assumed to have been at a depth of more than 100 m according to the vertical transition from iron oolite to glauconite facies that occurred in the condensed bed at the base of the Birmenstorf Member. The water depth must have increased beyond 100 m at the end of the Densiplicatum Subchron in Canton Aargau. The top of the Birmenstorf Member is two subchrons or about 600 000 years younger than the vertical iron-ooid-glauconite facies transition below. The water depth increased in this region during deposition of succession 1 by a substantial amount of relative sea-level rise plus some exogenic basement subsidence that was caused by loading of the lithosphere with the additional water. The average angle of slope of the top of the Pichoux Formation that is conspicuous because of superelevation in figure 173 was at the end of deposition of the unit between Sornetan and Péry only about 0.5°. The wedge-like geometry of the micritic Pichoux Formation is evidence that this accumulation of lime mud was derived from the carbonate platform of the St-Ursanne Formation.

The coral reefs of the Buix Member in the upper St-Ursanne Formation that were observed by Gressly (1838–1841, pl. 6) at Mt. Terri near Cornol and at Huggerwald near Kleinlützel can now be assumed to have grown at a water depth of less than 10 m. The coeval, uncondensed facies of the Birmenstorf Member in the epicontinental basin, a biostrome of siliceous sponges with abundant ammonites, was deposited at a depth of more than 100 m. Stromatolitic crusts at the upper surface of platy siliceous sponges (*Discophyma* sp.) as figured by Gygi (1992, fig. 32) are an indication that the normal facies of the Birmenstorf Member was sedimented in the photic zone. This is the "région des faciès à polypiers spongieux" of Gressly. The time equivalence of the Buix Member, of the upper, proximal part of the Pichoux Formation and of the uncondensed Birmenstorf Member is now documented by well-preserved ammonites that were figured by Gygi (1995, fig. 4 and 8, and 2001, fig. 85–87), and by the mineral stratigraphic correlation B of Gygi & Persoz (1986, pl. 1A). Hermatypic corals prevail in the macrofauna of the Buix Member, and ammonites associated with siliceous sponges are the main elements of the macrofauna in the Birmenstorf Member. The whole water column above the Birmenstorf Member was well-aerated. This is concluded from the rich benthic fauna that is not dwarf. The nutrient content of the water must have been low. This is indicated by the fact that Ghasemi et al. (1999:40) found very few marine palynomorphs in the Birmenstorf Member.

The vertical and the lateral succession of facies in succession 1 in northwestern Switzerland as represented in figure 173 well illustrates what is now known to many authors as "Walther's law".

8.4 Succession 2: Vorbourg, Röschenz and Hauptmumienbank Members and time equivalents

8.4.1 Vertical facies succession in succession 2 in northwestern Switzerland

8.4.1.1 Vorbourg Member

The Vorbourg Member as it is conceived now (Gygi, 2000a:58, and 2000b:142) is a succession of thickly-bedded, mostly micritic limestone with an average thickness of about 10 m. A small tidal channel that was discovered by Pümpin (1965, fig. 26) and an intertidal stromatolite with mud cracks (fig. 178) are evidence that the member was sedimented mainly in the intertidal zone. The occurrence of oncolite in the lowermost bed of the Vorbourg Member at Schützenebnetchopf near Kleinlützel, Canton Solothurn, at the elevation of 640 m at coordinates 600 150/254 010 (locality RG 396, polished slab Gy 4532) documents a shallow subtidal environment. The oncoids found in bed no. 15 of section RG 376 at Mont Chemin near Courrendlin, Canton Jura, in the middle Vorbourg Member (rock sample Gy 4373, thin section Gy 6336) were also formed in the shallow subtidal zone. The same environment is indicated by *Cladocoropsis* that was found in beds no. 42 (thin section Gy 6140) and 53 (thin section Gy 6142) of the Vorbourg Member in the unpublished section RG 362 south of Mt. Hasenschell near Movelier, Canton Jura. This may be the oldest occurrence of *Cladocoropsis* that was as yet recorded. The author knows of no ammonites that were found in the Vorbourg Member.

8.4.1.2 Röschenz Member

The Röschenz Member is a variable succession of marls and limestones with an average, compacted thickness of 35 m. This member is normally covered with vegetation. The only complete section of the member that could be measured was the temporary outcrop along the road from the village Röschenz, Canton Basel-Landschaft, down to the locality called Müli west of the village. This is section RG 402 that is represented in Gygi (2000a, pl. 33). Nerineid gastropods, ostreid bivalves and calcareous oolite indicate a marine, shallow subtidal environment. This is confirmed by the presence of algae like *Cayeuxia* and *Marinella* as well as by the foraminifer *Alveosepta*. No ammonites were found. The Röschenz Member begins near Saulcy, Canton Jura, with a stromatolite with planar to wavy lamination. This is bed no. 52 of the unpublished section RG 317. The polished slab Gy 4454 from this bed with dewatering cracks descending from the upper surface of the stromatolite was depicted by Gygi (1992, fig. 7). A stromatolite with birdseye pores is in bed no. 58 of section RG 359, a drinking water well, near Bressaucourt, Canton Jura. From this bed are the polished slabs Gy 4165 and Gy 4166 that are indicated in Gygi (2000a, pl. 18). The stromatolite in this section documents the intertidal zone. The polished slab Gy 4561 of a sample that was found beside the cantonal road in section RG 398, bed no. 3a near Liesberg, Canton Basel-Landschaft, about in the middle of the Röschenz Member (Gygi, 2000a, fig. 25 and pl. 32) is from a palaeosol with rootlets in the supratidal environment. Schneider (1960:7) reported hermatypic corals from locality Echaux, coordinates 569 870/249 220, near Bressaucourt (Canton Jura) in the uppermost part of the member. The corals could not be found again by the author in 1981 at the spot that was indicated by Schneider.

8.4.1.3 Hauptmumienbank Member

The Hauptmumienbank Member is a limestone succession with a mean thickness of about 5 m. It is characterized by primarily hard, calcareous algal nodules that were embedded in lime mud that is now normally a biomicritic groundmass (Gygi, 2000a, fig. 14). In the majority of the sections, the oncoids are increasingly abundant towards the top of the member. The greatest diameter of the oncoids is about 3 cm (Gygi, 2000a, fig. 14). Calcite pseudomorphs after calcium sulfate in some of the oncoids as figured by Gygi & Persoz (1987, fig. 2C) in the polished slab Gy 5164 from section RG 441, bed no. 3 beside the cantonal road near Liesberg, Canton Basel-Landschaft, are evidence that the figured algal nodules grew in hypersaline water. The Hauptmumienbank Member is a marker unit with a great areal extent that was laid down in a shallow lagoon. It occurs as far to the east as Wolschwiller (France) southwest of Basel (locality RG 395, polished slab Gy 4531), where the member is 5.1 m thick. Fischer (1965:19) mentioned this oncolite above the Röschenz (*olim*: Natica) Member in that area. The Hauptmumienbank Member was found to be ca. 4 m thick west of the village of Blauen, Canton Basel-Landschaft. There, the upper part of the member crops out in typical facies in the old, small quarry at the locality Rüti west-northwest of Blauen at coordinates 605 450/255 650 (locality RG 420, polished slab Gy 4899). Branching corals occur in the upper part of the member, and oolite is at the top of the outcrop. Mohler (1938:7) assigned this succession to the Verena Member, and Bitterli (1945:17) followed him in this. The quarry is the type locality of the foraminifer *Conicospirillina basiliensis* Mohler (1938:27, pl. 4:5). The age of this characteristic taxon is, according to correlations H and I by Gygi & Persoz (1986, pl. 1), the late Hypselum Subchron of the Bimammatum Chron. This is confirmed by the thin section Gy 6616 with *Conicospirillina basiliensis* Mohler from bed no. 75a of the Hauptmumienbank Member in section RG 402 near Röschenz, Canton Basel-Landschaft (Gygi, 2000a, pl. 33).

According to correlation H by Gygi & Persoz (1986, table 2 and fig. 10) the Hauptmumienbank Member also occurs in section RG 307 near Péry, Canton Bern, where it is represented by beds no. 198–201. Beds no. 202–211 of the section must maybe also be assigned to this member. The Hauptmumienbank Member was not indicated by Gygi (2000a, pl. 22) in section RG 307. The calcareous oolite with inclined bedding below the Hauptmumienbank Member (beds no. 193–195 of section RG 307, see fig. 181) was by error assigned to the Steinebach Member. The Hauptmumienbank Member was found in typical facies near Roches, Canton Bern, in the unpublished section RG 372 at Côte du Droit along the road from Hautes Roches to Le Trondai. The member in this section is represented by beds no. 49–50 that are together 5 m thick. Numerous specimens of the foraminifer *Paraurgonina*, the red alga *Solenopora* and some solitary corals were recognized in the two beds. The upper bedding plane of bed no. 50 is a planed erosion surface that intersects oncoids (polished slab Gy 4348, fig. 183). Borings with a diameter of as much as 2 cm descend from the upper bedding plane and penetrate into the upper part of the bed. The borings intersect oncoids. Bolliger & Burri (1970:74) renamed the member at this locality "Hautes Roches-Algenkalke" and included what is now called Laufen Member above in the unit, probably because they saw that what is bed no. 57 in the Laufen Member of Gygi's section RG 372 (polished slab Gy 4352) is an oncolite.

8.4.2 Lateral facies succession in succession 2

It can be read from figure 173 that the Vorbourg and the Röschenz Member grade laterally into the narrow carbonate platform of the Günsberg Formation. The upper Röschenz Member progrades over the proximal part of the platform. The carbonate platform of the Günsberg Formation is much narrower than the platform of the St-Ursanne Formation, probably because of the ample supply of argillaceous mud that bypassed the Günsberg platform in suspension. The clay minerals suspended in the water above the platform must have strongly reduced the rate of carbonate precipitation above the platform. The base of the Günsberg Formation is where coral bioherms appear above the Effingen Member. The bioherms grew laterally close to each other as can be seen in the quarry of La Charuque near Péry, Canton Bern (section RG 307, pl. 22 in Gygi, 2000a). The bioherms are individual knolls that did not coalesce into a barrier reef. They grew up to about 20 m high in section RG 307, but their top was never more than a few meters above the level sediment surface between them. This is evident from figure 19 in Gygi (1992). Allenbach (2001:276) thought he saw channels deeper than 15 m between the bioherms at this location. This could not be confirmed by the author. The coral bioherms at the base of the Günsberg Formation near Péry resemble in shape to the sponge bioherms in the Upper Jurassic of southern Germany that grew in deeper water.

The coral bioherms at the base of the Günsberg Formation prograded over the proximal part of the Effingen Member (fig. 173). The lithology of the Günsberg Formation above the coral bioherms at the base is very variable as can be read from several plates in Gygi (2000a). Detailed correlation mainly within the upper part of the formation is therefore as yet uncertain (see below), and subdivision into members is not recommended.

Parts of the Günsberg carbonate platform were probably twice subaerially exposed. This can be concluded from sections RG 307, RG 435 and RG 458 that were measured in different parts of the quarry of La Charuque near Péry, Canton Bern (pl. 22 in Gygi, 2000a). Tree branches as much as 2 cm thick and gyrogonites of characean algae were found at the upper bedding plane of the calcareous oolite no. 162 in section RG 307. A following transgression brought about sedimentation of an oncolite that locally includes hermatypic corals. This is the Grüne Mumienbank (Green Oncolite) of Ziegler (1956) that is represented as bed no. 163 of plate 22 in Gygi (2000a). The oncolite was sampled again as bed no. 9a in section RG 435 that was measured in 1986 in the quarry of La Charuque (not indicated in pl. 22 in Gygi, 2000a). The polished slab Gy 5059 of the Green Oncolite in section RG 435 was figured by Gygi (1992, fig. 14). Another subaerial exposure probably occurred when bed no. 178 of section RG 307 and the coeval bed no. 20 of section RG 435 were laid down. This is indicated by small tree branches. Both deposits of subaerial exposure are inconspicuous in the sections near Péry.

A supratidal environment is documented by the thin layer of lignite that could be sampled (rock sample Gy 7722) in a temporary outcrop beside the cantonal road in the southern part of Moutier gorge. This is the top of bed no. 80 in section RG 390 near Moutier, Canton Bern (pl. 27 in Gygi, 2000a). A thin lignite layer was visible for some time in the quarry at Gänsbrunnen, Canton Solothurn. This is bed no. 25 of section RG 430 that is represented as plate 40 in Gygi (2000a). It must be borne in mind that a thick layer of Recent peat occurs on Rodriguez Key, an emergent Holocene mudbank within the shallow sea of the Florida reef tract (Turmel & Swanson, 1976, fig. 16–17). Lignite in itself can therefore not be taken as proof of an extended land surface. The palaeosol with rootlets in the Günsberg Member of section RG 398, bed no. 3a (polished slab Gy 4561) near Liesberg (Gygi, 2000a, fig. 25, pl. 32) documents a supratidal environment. A planed erosion surface is evidence of subaerial exposure at the top of bed no. 49 of section RG 406 near Vermes, Canton Jura (polished slab Gy 4735). The surface was bored and encrusted with ostreids during a following transgression (Gygi & Persoz, 1986, fig. 5, see also Gygi, 2000a, pl. 37).

Coeval with bed no. 49 of section RG 406 on the north slope of Mt. Raimeux (Gygi, 2000a, pl. 37) is the intertidal stromatolite of bed no. 42 in the unplublished section RG 417 on the south slope of Mt. Raimeux near Crémines, Canton Bern. The prism (mud) cracks at the surface of the stromatolite (sample Gy 4831) are represented in figure 177. The isolated prism Gy 4795 from the coeval stromatolite of bed no. 21 of the nearby, unpublished section RG 414 near Grandval, was figured by Gygi (1992, fig. 6). The margins of this prism are upwarped by desiccation.

A major transgression occurred before the Hauptmumienbank Member was laid down. The considerable accommodation space created by the transgression is documented by the inclined bedding of the oolite (beds no. 193–195) below the Hauptmumienbank Member in section RG 307 near Péry (fig. 181 in this study and Gygi, 2000a, pl. 22), or by the cross-bedded calcarenite below the Hauptmumienbank Member beside the cantonal road near Liesberg in section RG 441, coordinates 600 950/250 420. The well-accessible outcrop near Liesberg was figured by Gygi & Persoz (1987, fig. 2A). The giant nautiloid *Paracenoceras ingens* Tintant et al. J 30716 (Tintant et al., 2002:437) from bed no. 38 in the upper Günsberg Formation in the unpublished section RG 414 near Grandval, Canton Bern (same section figured by Ziegler, 1962, pl. I/8b), is evidence that the transgression brought about a significant water depth. Because of this transgression, hermatypic corals could advance into the platform interior to Souboz, Canton Bern, where individual colonies up to 1.5 m wide and 0.5 m thick were found within marl below the Hauptmumienbank Member. This is bed no. 59 of the unpublished section RG 312. Associated with the corals is a rich macrofauna of brachiopods like *Zeillerina astartina* (Rollier), terebratulids and the rhynchonellid *Septaliphoria pinguis* (Roemer). Bivalves are represented in the bed by ostreids and pectinids. There are also some serpulids and sea urchins. Evidence of the transgression even further in the platform interior are the hermatypic corals reported by Schneider (1960:7) to occur in the uppermost Röschenz Member near Bressaucourt, Canton Jura (see above).

The "Steinibach-Schichten" that were discerned by Pfirter (1982, fig. 4) below the Hauptmumienbank Member for instance in Moutier gorge, or by Pittet (1996, fig. 19b) on Mt. Graitery near Moutier, are probably coeval with the predominantly oolitic unit that Gygi (2000a, pl. 37, beds no. 51–53) erroneously called Hauptmumienbank Member on the north slope of Mt. Raimeux near Vermes. This unit is often cross-bedded as for instance the "Steinebach Member" in section RG 307 near Péry, beds no. 193–195 in plate 22 by Gygi (2000a, see also fig. 181 in this study). Cross-bedded oolite in this stratigraphic position was also observed in bed no. 84 in section RG 400 near Corban (Gygi, 2000a, pl. 35), and in bed no. 31b in section RG 404 near Mervelier (Gygi, 2000a, pl. 36). Inclined bedding of this oolite unit is conspicuous in bed no. 38 in section RG 381 in Court gorge near Moutier (Gygi, 2000a, pl. 28). This is indicative of significant accommodation space that was created during a short time span by a pulse of eustatic sea-level rise during the Hypselum Subchron (Gygi, 1986, fig. 4). The coral biostrome of bed no. 39 above in section RG 381 in Court gorge corroborates the transgression.

The oncolite of the Hauptmumienbank Member (fig. 183) was sedimented in a shallow lagoon. The lagoon was rimmed by the belt of calcareous oolite of the Steinebach Member (fig. 173). The small coral bioherms of the lower Olten Member that are intersected in the Brändistal gorge northwest of Wangen near Olten grew off the distal margin of the Steinebach ooid sand shoal. The mineral stratigraphic correlation I by Gygi & Persoz (1986, pl. 1) indicates that the time equivalent of the Steinebach Member in Canton Aargau is the Geissberg Member. The Geissberg Member is a succession of micritic, thickly bedded limestone with a macrofauna in which bivalves prevail. The depth of deposition was locally slight, because the uppermost part of the member is a biocalcarenite in the Bözberg area west of Brugg as documented by Gygi (1969a, pl. 5, fig. 22). But the average water depth was probably greater than 20 m (fig. 187 C), because there are no hermatyic corals in the Geissberg Member. The Geissberg Member grades laterally into the lower Hornbuck Member in Canton Schaffhausen (fig. 173).

Sedimentation of the Hauptmumienbank Member and of the Steinebach Member ended when sea-level fell. Both members then became subaerially exposed at some localities. This is documented by the planed erosion surface that intersects oncoids of the Hauptmumienbank Member in the unpublished section RG 372 near Roches, Canton Bern (fig. 183), and by what is presumed to be a palaeosol above the Steinebach Member in the unpublished section RG 15, bed no. 3 (rock samples Gy 238, 239 and 3004, thin section Gy 7092) in upper Horngraben gorge near Aedermannsdorf, Canton Solothurn, and in the unpublished section RG 4, bed no. 40 B (rock samples Gy 49, 50 and thin sections Gy 2480, 2481) near Waldenburg, Canton Basel-Landschaft (fig. 176). The palaeosols of bed no. 3 of section RG 15 near Aedermannsdorf or of bed no. 15 of section RG 439 near Balsthal (fig. 175) have a groundmass of marly limestone and include large calcareous nodules of what is probably calcrete. Radially arranged, acicular calcite crystals are below the surface of the nodules. There are small grains of detrital quartz within calcite rays of bed no. 40 B of section RG 4 near Waldenburg (thin sections Gy 2480 and Gy 2481). The quartz grains are an indication that the calcite rays grew within a preexisting matrix. Such calcite rays occurring in a palaeosol have, to the knowledge of the author, never been described or figured so far. There are sections like RG 307 near Péry (Gygi, 2000a, pl. 22) or RG 454 near Bure in the platform interior (Gygi, 2000a, pl. 16) where no evidence of subaerial exposure or erosion was found at the top of the Hauptmumienbank Member.

Subaerial exposure of the top of succession 2 that occurred at the same time in northwestern Switzerland (Roches) at the top of the Hauptmumienbank Member, and near Aedermannsdorf or Waldenburg above the Steinebach Member, the fact that the combined thicknesses of successions 1 and 2 are almost equal between northwestern Switzerland and eastern Canton Solothurn (fig. 187C), and that sedimentation of the Late Jurassic began at a similar depth in all of this area, are evidence that endogenic subsidence was on average nearly uniform in that region during depositon of successions 1 and 2 (see below).

The Günsberg Formation grades laterally into the Effingen Member of the Wildegg Formation (fig. 173). The thickness of the Effingen Member in eastern Canton Solothurn is about 200 m northwest of Oensingen between the limestone ridges of Ravellen and Bränten, where strata are vertical. The thickness is about 210 m on the eastern slope of Mt. Born southwest of Olten to conclude from the difference in elevation between an outcrop of the Birmenstorf Member on the left bank of the Aare river as mapped by Mühlberg (1914) at the elevation of about 390 m, and the base of the cliff at about 600 m on Mt. Born to the west. Strata are near-horizontal in both outcrops. The thickness is about 200 m in the well of Pfaffnau (Gygi & Persoz, 1986, pl. 1A). It grows locally, probably caused by synsedimentary tectonics, to about 260 m near Riniken west of Brugg, Canton Aargau, to conclude from the log of the Nagra well and of an outcrop of the Crenularis Member to the west of the well (Gygi, 1990c, fig. 6). The thickness of the Effingen Member diminishes gradually to less than 50 m near Siblingen, Canton Schaffhausen. It was found to be but 14 m in the exploration well drilled by Nagra near Benken, Canton Zürich (Nagra 2001, Beilage 10.3).

The compacted, average thickness of the Effingen Member in eastern Canton Solothurn can be estimated at about 210 m. It was assumed above that sedimentation of the member began at a water depth that was somewhat greater than 100 m. Deposition of the member ended in this region at a depth of ca. 10 m, because the calcareous oolite of the Steinebach Member is above the Effingen Member in the unpublished section RG 448 in the quarry Mösliloch near Egerkingen in eastern Canton Solothurn (fig. 173). The Effingen Member is therefore in eastern Canton Solothurn a shallowing-upward succession that was sedimented into an initially starved, epicontinental basin.

Most of the Effingen Member is blue-gray, massive marl. Intercalated in the marl are beds or successions of beds with an elevated content of calcium carbonate. The most important of these carbonate-rich successions is the Gerstenhübel Beds, a pure, well-bedded micritic limestone unit that can be mapped in Canton Aargau (fig. 173). Gygi et al. (1998, fig. 10) drew attention to a large channel in the lowermost Effingen Member in a deep road cut near Veltheim, Canton Aargau (section RG 226). The filling of the channel may be a mud turbidite. A submarine truncation surface in the upper Effingen Member of section RG 37 near Auenstein is represented in figure 183. Above this surface is a debris flow (Gygi & Persoz, 1986, fig. 3, bed no. 102 of section RG 37, polished slab Gy 3115). Another example of debris flows, bed no. 98 in the same section, was published by Gygi & Persoz (1987, fig. 5, polished slab Gy 3113). Such flows can grade distally into small turbidites. This is concluded from the slump that occurred on the shore of Lake Zürich near Horgen in 1875, when part of the just completed railway station of Horgen subsided into the lake only a few days after railway traffic began (Heim, 1932:42). The slump was documented by Kelts & Hsü (1980) to grade laterally into a turbidite.

The debris flows in the upper Effingen Member of section RG 37 near Auenstein prove that this part of the member was sedimented on a depositional slope. Further evidence of the existence of a slope is correlation G by Gygi & Persoz (1986, pl. 1A) in the same section. The declivity of the slope cannot be established in this section. It was probably of the order of the angle at which the top of the ramp of the Pichoux Formation was laid down. This angle was established to have been about 0.5° between Sornetan (section RG 315) and Péry (section RG 307) in Canton Bern (see above). This was probably insufficient for the triggering of debris flows and turbidites. The declivity may have been significantly greater in the region south of Basel where the ramp of the Pichoux Formation is much narrower and consequently must have had a greater inclination as for instance between Himmelried and Seewen in Canton Solothurn.

The proximal Effingen Member below the Günsberg Formation (fig. 173) is therefore a stack of low-angle foresets or prograding sigmoids in the sense of Eberli & Ginsburg (1989, fig. 6), with a declivity of the same order of that given by these authors who found the inclination to be less than 5° on the western margin of Bimini Bank, Bahamas. The progradational internal structure of the proximal Effingen Member was represented in plate 1 A by Gygi & Persoz (1986). This is documented by the mineral stratigraphic correlations C, E, F and G. Further evidence is that it could be documented with ammonites that the whole of the Effingen Member in section RG 307 near Péry and in section RG 14 near Günsberg was laid down during the Bifurcatus Chron (fig. 173–174), whereas the upper part of the member near Auenstein was sedimented in the subsequent Hypselum Subchron of the Bimammatum Chron (fig. 173). The internal structure of the Wildegg Formation is therefore different from that of the Bärschwil Formation. The sigmoids of the proximal Effingen Member were laid down at a similar angle of slope as in the upper Effingen Member near Auenstein, where submarine debris flows are documented. This calls for a reevaluation of the mode of formation of the carbonate-rich bed with about 40% of fine-grained, angular detrital quartz (thin section Gy 6411) that smothered a population of starfish (Echinodermata, subclass Asteroidea) in the lowermost Effingen Member that crops out at the head of Schofgraben north of Mt. Weissenstein, on the territory of the village Rüttenen, Canton Solothurn, at coordinates 606 140/234 100. The author discovered the first two starfish at this locality in the drift in 1963. He gave the specimens to H. Hess, who described them as *Pentasteria longispina* n.sp. (Hess, 1968). The Schofgraben outcrop is positioned in figure 173 of the present study between Péry and Günsberg.

The starfish of Schofgraben were later found to occur in excellent preservation in a bed with a thickness of about 15 cm that is ca. 6 m above the top of the Birmenstorf Member (Hess, 1975, pl. 1). Meyer (1984) reported that the bed was excavated in 1979 on a surface of 12 m^2 at this locality and that it yielded 190 starfish. Hess (1968, pl. 1) documented that the bed is indistinctly laminated directly above a starfish. Indistinct lamination is also visible in thin section Gy 6411 of the bed. Hess (1968:612) concluded from the lamination that the starfish figured by him was rapidly smothered. Meyer (1984, fig. 11) thought that the fossil bed in Schofgraben was a succession of several tempestites that was deposited by subsequent storms without intervening normal sedimentation.

A depth of deposition somewhat greater than 100 m must be assumed for the starfish bed in Schofgraben to conclude from what is stated above. It cannot be ruled out that a particularly strong storm could rework sand-grade sediment at this depth. Schaefer (1962:107), as cited from Hess (1968:613), wrote that the Recent relatives of *Pentasteria, Asteropecten irregularis*, can be smothered alive by sediment supplied by a storm so rapidly and deep enough that the starfish cannot free themselves and die. This process would explain the perfect preservation of the starfish in Schofgraben. However, the occurrence of several storms that were strong enough to resuspend and transport sand-grade sediment at this depth, and succeeding after time intervals so short that no normal sedimentation could intervene in the Schofgraben fossil deposit, as was assumed by Meyer (1984), is unlikely. A single turbidite must be envisaged as a possible process of deposition of the starfish bed. Distal turbidites with about the same thickness were found by Walker & Mutti (1973, fig. 9) and by Mutti (1977). The starfish deposit in Schofgraben was probably laid down on a surface with a very slight angle of slope. This does not exclude a turbidite, because Crevello & Schlager (1980:1144) stated that a carbonate turbidity current traveled a distance of 100 km over the basin floor of Exuma Sound, Bahamas, at a declivity of only 0.5°. This is the order of slope that probably existed at the toe of the prograding sigmoids of the proximal Effingen Member (fig. 173).

The debris flows in the upper Effingen Member near Auenstein that traveled on a surface with a slight declivity, are evidence that thin-bedded turbidites *could* occur in the lowermost, proximal Effingen Member. The debris flows may have been triggered by small earthquakes that were caused by motion along a synsedimentary fault as is represented in figure 183. Tempestites as were assumed by Meyer (1984) to exist in the lower Effingen Member are common in the uppermost Effingen Member of section RG 307 near Péry (Gygi, 2000a, pl. 22, beds no. 125–157). Characteristic is the unpublished polished slab Gy 3440 from bed no. 125 of section RG 307 with an erosional surface at the top. The polished slab Gy 3452 of the tempestite from the younger bed no. 160e beside a coral bioherm in section RG 307 at Péry (lower Günsberg Formation) was figured by Gygi (1986, fig. 7). Another typical tempestite is the polished slab Gy 190 that was taken from the upper, marly part of the Günsberg Formation in section RG 14, bed no. 179, in the Gschlief landslide near Günsberg, Canton Solothurn (not figured, see Gygi, 1969a, pl. 18, laminated beds no. 169–183).

The sedimentation rate of the Effingen Member was at the beginning relatively low (Gygi, 1999, fig. 2). This is documented by the abundant starfish in Schofgraben (see above) and by the siliceous sponges and ammonites that are common in the lowermost Effingen Member near Auenstein (section RG 226, Gygi, 1973, fig. 3) and near Holderbank (section RG 276, Gygi et al., 1979, fig. 3), both in Canton Aargau. Then, the sedimentation rate increased very much, and the oxygenation of the bottom water dropped to a level that caused ammonites to be dwarfed and preserved as casts of iron sulfide in the marl ca. 10 m below the Gerstenhübel Beds in section RG 226 near Auenstein. The oxygen content of the bottom water must have been variable during deposition of the Effingen Member, because there are about 100 ammonites from the Effingen Member in the quarry of Hinterstein near Oberehrendingen, Canton Aargau, in the collection of L. Rollier at the ETH Zürich. This fauna was studied by Enay in Enay & Gygi (2001) and was dated at the Grossouvrei Subchron of the Bifurcatus Chron. The horizon of the fauna in the quarry is not recorded in Rollier's field books that were scanned by the author at the ETH. Enay & Gygi (2001:448) concluded from the age of the fauna that the ammonites were collected from the lower part of the Effingen Member, possibly at about the level of the Gerstenhübel Beds (op.cit., p. 475). Enay in Enay & Gygi (2001:475) noted that the size of adult *Dichotomoceras* in this fauna is less than normal, and concluded that this may be the consequence of a reduced oxygen content of the bottom water. Gygi (1969a:61) found bivalves and gastropods that are smaller than 1 mm and are preserved as casts of iron sulfide in bed no. 54 of section RG 37 near Auenstein. Benthic foraminifera are rare in this marl (Gygi & Stumm, 1965:23, sample no. 3). The marl is only a few meters below a limestone succession with the adult *Euaspidoceras hypselum* (Oppel) J 27259, an ammonite of normal size that was figured by Gygi (2000a, pl. 10, fig. 1).

The oxygen content of the bottom water was probably strongly reduced when the marl below the Gerstenhübel Beds was deposited, and then rose to slightly reduced when the ammonite fauna of Oberehrendingen lived. The oxygen content of the water must have been low again during part of the Hypselum Subchron of the Bimammatum Chron. The curve of oxygen content of the water that was drawn by Gygi (1999, fig. 2) is then too simple. Bivalves of the genus *Pholadomya* in the uppermost Effingen Member of section RG 37 near Auenstein are of normal size and indicate normal oxygenation of the bottom water. The rich and diverse dinoflagellate flora that Ghasemi et al. (1999) found through the whole thickness of the Effingen Member in that section is evidence that the upper part of the water column was at all times normally oxygenated during deposition of the member. This is corroborated by the coral bioherms that began to grow at close horizontal interspace at the top of the Effingen Member as can be seen in the quarry of La Charuque near Péry, Canton Bern (Gygi, 1992, fig. 19, or Gygi, 2000a, pl. 22).

8.5 Succession 3: Bure, La May and Porrentruy Members and time equivalents

8.5.1 Vertical facies succession in succession 3 in northwestern Switzerland

8.5.1.1 Bure Member

Succession 3 begins in northwestern Switzerland with a gray marl with a total thickness of about 10 m. This unit was formerly known under the name Humeralis marl. It was renamed Bure Member by Gygi (1995:11) after the village Bure in northern Canton Jura, where a complete section of the member was provided by the exploration well BUR 2 for the Transjurane superhighway. The well log was published as section RG 454 by Gygi (2000a, pl. 16). There are thin intercalations of marly limestone mainly near the base of the member. The Bure Member is the youngest member of the Vellerat Formation. No dinoflagellates could be found in this member by Ghasemi et al. (1999). Macrofossils are uncommon. Small ostreids, serpulids, parts of crinoid stems and the foraminifer *Alveosepta* were recorded in bed no. 17 of section RG 443, an exploration well drilled beside la Coperie farm near St-Ursanne, Canton Jura. The well log is represented as plate no. 20 in Gygi (2000a). The age of the member can only be concluded from its position above the Hauptmumienbank Member. The top of the Hauptmumienbank Member coincides with the mineral stratigraphic correlation I of Gygi & Persoz (1986, pl. 1A) and with sequence boundary O 7 of Gygi et al. (1998). According to figure 40 in Gygi (2000a), the age of the Bure Member is the Bimammatum Subchron of the Bimammatum Chron.

8.5.1.2 Courgenay Formation

8.5.1.2.1 La May Member

The Courgenay Formation was named by Gygi (1995:12). There are two members in the formation. The La May Member below (Gygi, 1995:12) is a micritic, well-cemented and well-bedded limestone. It includes micritic lithoclasts with a diameter not exceeding 1 cm. There are normally few macrofossils in the member like bivalves of the genus *Pholodomya* and the colonial worms *Cycloserpula socialis* (Goldfuss). A mass occurrence of small ostreids was found in the lower part of the member in a road cut at the locality Combe des Pierres near Bure, Canton Jura. This is documented by the polished slab Gy 4081 from bed no. 10 of the unpublished section RG 348. There are micritic lithoclasts with a diameter of up to 5 cm in this bed. The small brachiopod *Zeillerina astartina* (Rollier) that was called *Zeilleria humeralis* by earlier authors (according to Enay et al., 1988:314) was found in beds no. 6 and 9 of the section. Further up in the section are bivalves of the genera *Pinna, Pleuromya, Pholadomya, Trigonia* and *Trichites.* These are accompanied by the rhynchonellid brachiopods *Septaliphoria pinguis* (Roemer) that are, according to Boullier (1993, fig. 2), indicative of very shallow water. *Septaliphoria pinguis* (Roemer) also occur in the lowermost La May Member at locality RG 386, Droit de Folpotat near Soulce, Canton Jura, and in the uppermost Günsberg Formation at the locality Montaigu near Souboz, Canton Bern (bed no. 59 of the unpublished section RG 312). All of these fossils and the large lithoclasts are evidence of very shallow water. The La May Member is somewhat more than 30 m thick in the exploration well for the Transjurane superhighway beside the farm La Coperie near St-Ursanne, Canton Jura. The well, section RG 443 (pl. 20 in Gygi, 2000a), is the only known section in which the La May Member is complete.

8.5.1.2.2 Porrentruy Member

Above the bedded La May Member is the massive Porrentru Member (Gygi, 1995:12). This pure, unbedded limestone i typically white and porous as in section RG 340 in the ol quarry east of Banné hill near Porrentruy, Canton Jura (Gygi 2000a, pl. 17, bed no. 88). Nerineid gastropods in this bed ar evidence of very shallow water. The nerineids are associate with solitary corals, bivalves and some lithoclasts with a diam eter of up to 2 cm. The top of the member is in this section corroded bedding plane that is encrusted with limonite (roc sample Gy 3991).

8.5.2 Lateral facies succession in succession 3

The argillaceous Bure Member grades in the distal directio into the Oolithe rousse Member (fig. 173). This is a calcareou oolite with a texture ranging from wackestone to grainston Grainstones are locally cross-bedded. The coarse-grained, sec ondary calcite B cement between the ooids can be ferroan. Th surface of the ooids is encrusted with limonite. This gives th weathered rock its characteristic brown colour. Dolomit rhombs often replaced the greater part of the groundmass c argillaceous wackestones and packstones. The surface of thes crystals is encrusted with limonite. Then the rhombs wer replaced by a mosaic of anhedral calcite (Gygi & Perso 1986:413). The environment of deposition and the diagenesi of this peculiar rock are as yet not fully understood.

The Oolithe rousse Member of the uppermost Vellerat Forma tion and the lower part of the La May Member of the lowe Courgenay Formation grade laterally into the Laufen Memb of the lower Balsthal Formation (fig. 173). The Laufen Mem ber is a limestone unit with a very variable compositon. It i cludes at some localities thin intercalations of oncolite th were appropriately called accessory oncolites by Ziegler (195 in order to distinguish them from the oncolitic Hauptmumie bank Member below that is a widespread, isochronous mark unit. The oncolites of the Laufen Member have only local e tent, they occur at different levels and cannot be correlate The Laufen Member includes bedded lime mudstone, oolit wackestone to grainstone and oncolitic wackestone. T oolitic facies is the well-known Laufen building stone that still exploited in quarries in Schachlete valley near Ditting north of Laufen, Canton Basel-Landschaft. One of the quarries is the unpublished section RG 457. The *Lith cosphinctes* sp. as figured by Gygi (1995, fig. 20) was found bed no. 4 of this section (oral communication by J. Jerman Wehren of Dittingen who found the ammonite). Hermatyp corals occur locally, but are uncommon in the Laufen Mer ber.

The mostly massive Verena Member is above the bedd Laufen Member. This is well visible near Liesberg (Gy 2000a, fig. 35, see also pl. 32, section RG 398). The limesto quarry of the former cement works of Liesberg is a complete section of the Verena Member (section RG 398). Most of the Verena Member is calcareous oolite. An isolated, small coral bioherm within the oolite was found north of Lommiswil, Canton Solothurn, at the crest of the Weissenstein range east of Mt. Hasenmatt. A forest road crosses the crest in a cut at point 1299. The bioherm, locality RG 383, is ca. 110 m east of the road cut at coordinates 601 680/232 390. The bottom of the bioherm is about 10 m above the base of the Verena Member. The bioherm is only 3 m high and includes mainly branching corals (rock sample Gy 4410, polished slab Gy 4408). Coral bioherms were also found in the Verena Member of section RG 419 near Seehof, Canton Bern, in the gorge south of locality Bächlen. The bioherms weather out of bed no. 104 of the section, and another bioherm is intersected by the road in bed no. 105 (polished slab Gy 4896). The bioherms are represented in figure 173. They are evidence of water with a normal salinity and of adequate water circulation where the bioherms grew.

On the other hand, partial dolomitization occurred in a large part of the Verena Member and of the upper Holzflue Member (Gygi, 1969a:77, pl. 13:47; Gygi, 2000a, fig. 26, 30). An above-normal salinity of the water is indicated by pseudomorphs of calcite after calcium sulfate in thin section Gy 6532 from bed no. 53 of the lower Verena Member in section RG 398 near Liesberg, Canton Basel-Landschaft (Gygi, 2000a, fig. 26, pl. 32). The sulfate content of the rock can be locally much greater. More than half of the rock volume in the upper part of bed no. 113 in the Verena Member of section RG 400 in the gorge northeast of La Providence farm near Corban, Canton Jura, is gypsum (Gygi, 2000a:45, pl. 35, thin section Gy 7706). This is evidence that the salinity of the water was locally much above normal during deposition of the Verena Member. No ammonites were ever found by the author in the member.

The Laufen Member and the Verena Member cannot be distinguished in the type section of the Balsthal Formation in Steinebach gorge north of Balsthal, Canton Solothurn (Gygi, 2000a, section RG 438, pl. 44). Gygi (1969a:86) therefore proposed the name Holzflue Member for the region between Balsthal and Olten. The Holzflue Member is mainly a calcareous oolite near Balsthal, but an intercalation of lime mudstone appears already in bed no. 13 of section RG 440 in the gully that descends southward east of the summit of Mt. Rüttelhorn. The section is about 7 km west-southwest of Balsthal on the territory of the village Rumisberg, Canton Bern (Gygi, 2000a, pl. 43). The lime mudstone intercalation reappears at the same level near Balsthal in section RG 438 in Steinebach gorge (middle part of bed no. 44, see Gygi, 2000a, pl. 44), and in section RG 450 at the cliff of Chluser Roggen below point 702, from 37 to 39 m below the top of the section (Gygi, 2000a, fig. 37). The content of calcareous ooids gradually decreases in the Holzflue Member from the unpublished section RG 448 in the quarry Mösliloch at Egerkingen, Canton Solothurn, towards the east. At the same time, the thickness of the member diminishes significantly (fig. 173). At the distal boundary of the Balsthal Formation, in the region of Olten, is the coral limestone of the Olten Member. Platy coral colonies prevail in this member with a matrix of lime mudstone that is probably, as a whole, a biostrome. Small bioherms were recorded only in the lowermost part of the member in the small gorge northwest of Wangen near Olten. The growth potential of hermatypic corals in the Olten Member was apparently weak. Coral growth ceased during the Planula Subchron when water depth became greater than about 20 m during a relative sea-level rise. The rate of relative sea-level rise was greater than the rate of sedimentation of calcareous mud at this time. There is no evidence of what prevented growth of corals in the Olten Member to keep up with sea-level rise.

The upper boundary of succession 3 can be easily mapped between Porrentruy (section RG 340, pl. 17 in Gygi, 2000a) and Mt. Rüttelhorn 7 km south-southwest of Balsthal (section RG 440, pl. 43 in Gygi, 2000a). The boundary is on top of the massive Porrentruy Member or of the massive Verena Member, respectively. Above is the well-bedded limestone of the Reuchenette Formation. The boundary is conspicuous in most pertinent sections (Gygi, 2000a, fig. 38). According to the mineral-stratigraphic correlation L by Gygi & Persoz (1986, pl. 1 A), the formation boundary almost coincides in that region with the boundary between the Planula and the Platynota Zone. The situation is different near Balsthal, where the boundary between the Balsthal and the Reuchenette Formation is best placed at the base of the palaeosol that is conspicuous in the upper part of the cliff of Chluser Roggen (Gygi, 2000a, fig. 37). The ammonite *Lithacosphinctes evolutus* (Quenstedt) J 30530 was found by B. Martin and P. Tschumi 2.6 m below that palaeosol, in what is now bed no. 9 in the unpublished section RG 439 at Innere Klus near Balsthal. The ammonite was identified by F. Atrops (Lyon), who assigned it to the earliest Platynota Chron. The specimen was shortly described and figured by Gygi (1995, fig. 19). It is because of this ammonite that Gygi (2000a, pl. 44) placed the Balsthal/Reuchenette formation boundary at the base of bed no. 50 in his section RG 438, below the palaeosol. This is impracticable for mapping near Balsthal.

Succession 3 begins in Canton Aargau with the lowermost lime mudstone bed with glauconite of the Crenularis Member. This is bed no. 32 of section RG 62 that crops out beside the road from Villigen to Mt. Geissberg (Gygi, 1969a, pl. 17). Section RG 62 is the type section of the Villigen Formation. The section was assembled from discontinuous outcrops. As a first step, drawings were made of the patchy outcrops on both sides of Ampflete valley southwest of Villigen from the opposite margins of the Geissberg plateau. Then the sections of the individual outcrops were measured bed-by-bed, beginning at the bottom of Ampflete valley. The partial sections could be assembled, because they somewhat overlap. The succession of beds with different thicknesses was compared between the overlapping parts of the sections and was used for correlation much like the sequence of growth rings with a varying thickness in ancient tree logs is used in dendrochronology. The composite section RG 62 in Ampflete valley was then checked by comparing it with the coeval part of section RG 63 only 300 m to the northeast (represented in Gygi, 1969a, pl. 19, upper section). Section RG 63 was measured on the rope west of the village of Villigen, down the cliff north of Besserstein spur. Bivalves of the genus *Pholadomya* prevail in the Crenularis Member of section RG 63. Bivalves are also the predominant element of the macrofauna in the porous, white upper part of the bedded lime mudstone of the Wangen Member in section RG 62. Moesch (1867) named the Wangen Member as it is now conceived after the porous, white limestone in the upper Holzflue Member near Wangen west of Olten. The white limestone of Wangen, Canton Solothurn, corresponds to beds no. 42–44 in section RG 21 in the quarry on Mt. Born near Olten (Gygi, 1969a, pl. 18). According to the mineral stratigraphic correlation J in plate 1 A by Gygi & Persoz (1986), the local facies of white limestone near Wangen west of Olten is younger than what is now called Wangen Member further east in Canton Aargau (fig. 173).

A complete section of succession 3 is exposed in the large quarry near Mellikon, Canton Aargau (RG 70, Gygi, 1969a, pl. 17). The glauconitic Crenularis Member is there replaced by sponge bioherms. Part of a sponge bioherm in section RG 70 was depicted by Gygi (1992, fig. 23). The Crenularis Member in typical facies with mostly bivalves and abundant glauconite, and with a thickness of less than 3 m, can be followed from Schönenwerd west of Aarau (unpublished section RG 28, beds no. 5–7) to Baldingen in northeastern Canton Aargau (unpublished section RG 69, beds no. 128–134). Section RG 69 near Baldingen is less than 2 km from the large quarry near Mellikon. Ammonites are relatively common mainly at the base of the sponge bioherms of section RG 70 near Mellikon (Gygi, 1969a, pl. 17). Only one ammonite was found in the bedded lime mudstone of the Wangen Member above in that section. The Knollen Bed in section RG 70 is represented by beds no. 59–62. Beds no. 51–58 of this section should be assigned, contrary to Gygi (1969a, pl. 17), to the upper Wangen Member. According to current knowledge as summarized by Gygi (2000a:108), it is probable that the Kimmeridgian Stage begins in section RG 70 with bed no. 59. Above the Knollen Bed, the abundance of ammonites increases from the base to the top of the Letzi Member. Ammonites prevail in the macrofauna of the bedded lime mudstone of this member.

North of the Rhine river, in southern Germany and in Canton Schaffhausen, the time equivalent of the Wangen Member is called Küssaburg Member, and the Letzi Member Wangental Member (fig. 173). The facies difference between the members of the two regions is insignificant. The only justification of different names for the very similar members of well-bedded lime mudstone is historical. The lower boundary of succession 3 is well-defined from northwestern Switzerland to section RG 69 near Baldingen southwest of Mellikon. The boundary could not be identified in section RG 70 near Mellikon. In Canton Schaffhausen, the boundary is within the Hornbuck Member at a level that could not yet be established. Ammonites prevail in the macrofauna of the whole Villigen Formation in Canton Schaffhausen.

The upper boundary of the Villigen Formation almost coincides with the boundary between the Galar Subzone of the Planula Zone below and the Platynota Zone above in excavation RG 239 at locality Summerhalde near Schaffhausen (fig. 160). The formation boundary can be exactly dated in this major excavation. *Sutneria (Sutneria) galar galar* (Oppel) J 23622 and *Sutneria (Sutneria) platynota* (Reinecke), morphotype A Schairer J 23630 from excavation RG 239 near Schaffhausen were figured by Gygi (2000a, pl. 13:2–3). The same taxa from section RG 70 near Mellikon are represented here: *Sutneria (Sutneria) galar galar* (Oppel) J 32809 from bed no. 114 in figure 64 and *Sutneria (Sutneria) platynota* (Reinecke), morphotype A Schairer J 32810 from bed no. 120 in figure 159b.

8.6 Lower Reuchenette Formation and time equivalents

The Reuchenette Formation was named by Thalmann (1966:32) after what was originally the hamlet called La Reuchenette on the territory of the village of Péry, Canton Bern. A detailed investigation of the type section of the formation near Péry and of other good sections in the Pichoux gorge near Sornetan and in the southern part of Court gorge near Court (all in Canton Bern) was published by Colombié (2002). The mappable base of the formation (see above) is the base of bed no. 235 in section RG 307 at Péry (Gygi, 2000a, pl. 22). The age of the formation boundary in section RG 307 at Péry, Canton Bern, is assumed to be coeval with the boundary between the Letzi Member of the upper Villigen Formation below and the Baden Member above in Canton Aargau. This was concluded according to correlations with the clay mineral kaolinite by Persoz in Gygi & Persoz (1986, fig. 14). In section RG 70 at Mellikon, Canton Aargau, the upper boundary of the Villigen Formation is at the top of bed no. 119. *Sutneria (Sutneria) platynota* (Reinecke) J 32810 (fig. 158) was found in bed no. 120 of the lowermost Baden Member above.

There is an intertidal stromatolite (fig. 184) 3.5 m above the base of the type section of the Reuchenette Formation in section RG 307, bed no. 236 near Péry (Gygi, 2000a, pl. 22, polished slab Gy 3488). A wavy laminated stromatolite without birdseye pores that is probably from the upper intertidal zone (compare with Gygi, 1992:811, fig. 12–13) was found in bed no. 72 of section RG 404 near Mervelier, Canton Jura, about 2 m above the base of the Reuchenette Formation (polished slab Gy 4716, pl. 36 in Gygi, 2000a). Black pebbles with a diameter of up to 2 cm occur at the top of bed no. 13 of section RG 431 at Gänsbrunnen, Canton Solothurn (rock sample Gy 4995, pl. 40 in Gygi, 2000a) about 2.5 m above the base of the Reuchenette Formation. An intertidal stromatolite with birdseye pores (polished slab Gy 4957) is in bed no. 41 of section RG 429 near Welschenrohr, Canton Solothurn, about 1 m above the formation boundary (pl. 39 in Gygi, 2000a). At Oberdorf, Canton Solothurn, in section RG 433 in the quarry north of Wäberhüsli, the upper bedding plane of bed no. 19 is a planed and bored erosion surface (Gygi, 2000a, pl. 41) that is 5.6 m above the base of the Reuchenette Formation. The corresponding bed, no. 20 in section RG 440 near Rumisberg, Canton Bern, east of the summit of Mt. Rüttelhorn, south of the crest, is a wavy laminated stromatolite with birdseye pores and a thickness of 60 cm. The upper bedding plane of the stromatolite is an uneven, probably subaerial erosion surface with a relief of as much as 15 cm that intersects the laminae of the stromatolite (Gygi, 2000a, pl. 43, polished slab Gy 5157). The stromatolite begins in section RG 440 3.5 m above the base of the Reuchenette Formation.

A palaeosol at the base of the Reuchenette Formation was observed in three sections near Balsthal, Canton Solothurn. The matrix of the bed, no. 52 of section RG 438 about in the middle of the tunnel of the road through Steinebach gorge (Gygi, 2000a, pl. 44), is a soft, greenish marl with a thickness of 0.35 m. Calcareous nodules with a diameter of centimeters to more than a decimeter are embedded in the marl. The nodules are recrystallized to fine-grained, saccharoidal calcite spar (thin section Gy 7307). In section RG 439 (unpublished) west of Innere Klus, the palaeosol is 0.45 m thick (bed no. 15). The base of the bed is a hummocky, probably subaerial erosion surface. Cones built of calcite rays grow to an elevation of as much as 10 cm above the hummocky surface at the base of the palaeosol. The matrix of the palaeosol is marl. The large calcareous nodules in the marl are recrystallized like in bed no. 52 of section RG 438. The nodule Gy 5142 from bed no. 15 of section RG 439 has a diameter of about 15 cm. A small druse at the centre of the nodule is entirely filled with anhedral calcite spar. Calcite rays grew inward perpendicularly to the surface of the nodule (fig. 175).

The relief of the subaerial erosion surface below the palaeosol was observed to be at least 1 m at the cliff of Chluser Roggen below point 702 near Balsthal. The surface is the base of bed no. 7 of the unpublished section RG 450 that was measured on the rope. This is evidence of an extended time of subaerial exposure. The palaeosol was measured in section RG 450 to be 0.6 m thick. It weathers back as a hollow that is conspicuous when seen from a vantage point on Wannenflue rock on the opposite side of the valley (Gygi, 2000a, fig. 37). The vantage point is at the end of a good forest road above Walderalp on the territory of Niederbipp, Canton Bern. The calcareous nodules in the palaeosol of Chluser Roggen (rock sample Gy 5237), as seen in thin section Gy 7433, are fine-grained calcite spar with few small and angular grains of detrital quartz.

There is reason to believe that the palaeosol near Balsthal, the planed and bored erosion surface near Oberdorf, and the stromatolites elsewhere above the base of the Reuchenette Formation are coeval. The ammonite *Lithacosphinctes evolutus* (Quenstedt) J 30530 that was found about 2.6 m below the palaeosol in section RG 439 near Balsthal (see above) is evidence that formation of the palaeosol began some time after the beginning of the Platynota Chron. Further east in section RG 21 at Mt. Born near Olten, the *Orthosphinctes (Orthosphinctes) uresheimensis* (Wegele) J 23085 (fig. 66) of the Middle Platynota Chron was found in bed no. 54 of section RG 21 (Gygi, 1969a, pl. 18). Ammonites of the Hypselocyclum Chron were found *in situ* in that section from bed no. 57 about 12 m above the base of the Reuchenette Formation upward (beds no. 57–59 of section RG 21). The ammonite *Balticeras pommerania* Dohm J 32816 of the Late Hypselocyclum Chron (fig. 80) is from bed no. 59 of section 21. This is evidence that the Platynota Zone is relatively thick and that the Hypselocyclum Zone is rather thin in section RG 21 near Olten. The situation is probably similar near Oberbuchsiten further west (see below).

The lowermost Reuchenette Formation is laterally replaced in Canton Aargau by the Baden Member (fig. 173). Complete sections of the Baden Member are near Villigen (section RG 62) and in the large quarry near Mellikon (section RG 70). Beds no. 120–123 of section RG 70 as discerned by Gygi (1969a, pl. 17) in the western part of the quarry near Mellikon merge with the thick bed no. 124 further east in the quarry where the bulk of the ammonites of section RG 70 was found. *Sutneria (Sutneria) platynota* (Reinecke), morphotype A Schairer J 32810 (fig. 159a) of the Early Platynota Chron was collected from bed no. 120 of section RG 70. Very few, or possibly no ammonites that are certainly younger than the Late Hypselocyclum Chron occur in the glauconitic, marly limestone of the lower Baden Member (bed no. 124) in section RG 70 (see fig. 170). The *Idoceras hararinum* Venzo J 24356 (fig. 97) from bed no. 124 was erroneously identified by Gygi (2000b:126) as *Idoceras balderum* (Oppel). *Idoceras hararinum* Venzo occurs in Switzerland below *Idoceras balderum* (Oppel) and is therefore now thought to be of late Hypselocyclum age (fig. 170). The combined thicknesses of the Platynota and of the Hypselocyclum Zone then amount to only somewhat more than 1 m in eastern Canton Aargau.

No ammonites were found in the marl of the upper Baden Member neither in section RG 62 on Mt. Geissberg near Villigen (bed no. 122, Gygi, 1969a, pl. 17), nor in section RG 70 near Mellikon (bed no. 125). The marl is thought to be time-equivalent with the Crussoliensis-Mergel in southern Germany and is therefore assigned tentatively to the Divisum Subchron of the Divisum Chron. Above the marl is a succession of well-bedded lime mudstone both near Villigen and near Mellikon. *Pseudhimalayites uhlandi* (Oppel) J 32927 (not figured) was collected from bed no. 126 in section RG 70 near Mellikon. Gygi (2000a, pl. 14:3) figured the *Idoceras balderum* (Oppel) J 31719 that was found in the lowermost Wettingen Member of section RG 62 near Villigen (bed no. 124). The vertical ranges of *Pseudhimalayites uhlandi* (Oppel) and of *Idoceras balderum* (Oppel) are therefore almost the same in northern Switzerland (fig. 170).

8.7 The bathymetric profile in Early Kimmeridgian time in northern Switzerland

At Balsthal, Canton Solothurn, a palaeosol was formed in Platynota time. A perisphinctid ammonite of the Early Platynota Chron was found 2.6 m below the palaeosol in section RG 439 at Innere Klus near Balsthal within calcareous oolite (see above). The subaerial horizon and the ammonite that was found below are taken as evidence that the average water depth in Platynota time was about zero near Balsthal. At Schaffhausen, muddy marine sediment of the lower Schwarzbach Formation was laid down during the Platynota Chron (fig. 160). There, the water depth cannot be concluded from the sediment. Only the macrofauna gives an indication of palaeodepth. Ammonites are the main element (more than 80%) of the macrofauna of Platynota age in excavation RG 239 at Summerhalde near Schaffhausen (fig. 188B). 46% of the ammonites are perisphinctaceans. Siliceous sponges are very abundant and well-preserved in the middle Schwarzbach Formation of Hypselocyclum age on Siblinger Randen near Siblingen west of Schaffhausen. These sponges and some ammonites were collected in a plowed field at locality RG 216.

Some information about palaeodepth near Schaffhausen in Platynota time can be obtained by comparing the lateral facies transition between Balsthal and Schaffhausen in Early Kimmeridgian time with the lateral facies transition between northwestern Switzerland and Canton Aargau in the Middle Oxfordian. Calcareous oolite with coral bioherms indicate a water depth of at most 10 m in the Tiergarten Member of the upper St-Ursanne Formation. The few ammonites occurring near St-Ursanne in the coeval Buix Member that was laid down in a lagoon at a depth of less than 10 m are all perisphinctids. The muddy sediment of the coeval, normal facies of the Birmenstorf Member in Canton Aargau includes a macrofauna with abundant siliceous sponges and with a rich ammonite assemblage. Perisphinctaceans are 44% of the ammonites in the Birmenstorf Member (table 80). The vertical transition from iron-ooid accretion to the formation of glauconite pellets occurred in the condensed bed at the base of the Birmenstorf Member and indicates a water depth of about 100 m. The normal facies of the Birmenstorf Member must then have been deposited at a depth that was greater than 100 m.

Perisphinctaceans are the only ammonites known to occur in the lagoonal sediment from very shallow water of the Buix Member in the upper St-Ursanne Formation. In the deeper water of both the Birmenstorf Member and of the Schwarzbach Formation, perisphinctaceans are less than 50% of the ammonite fauna. Haplocerataceae are more than 50% of the ammonites in the Birmenstorf Member of Canton Aargau (table 80), and 24% in the lower Schwarzbach Formation near Schaffhausen in excavation RG 239 at Summerhalde (fig. 188A). The percentage of Haplocerataceae in the ammonite fauna grows with increasing water depth, and the percentage of perisphinctaceans diminished from shallow to deeper water (see below). This is evidence that the Schwarzbach Formation in Canton Schaffhausen was sedimented in relatively deep water.

8.8 Relation between water depth and the composition of the macrofauna in Early Kimmeridgian time

8.8.1 Balsthal

The age of the palaeosol at the base of the Balsthal Formation near Balsthal is probably the Platynota Chron to judge from the ammonite *Lithacosphinctes evolutus* (Quenstedt) J 30530 that was found 2.6 m below the palaeosol. The thickness of the sediments laid down near Balsthal during the Platynota Chron must be considerable. This can be assumed by a comparison with section RG 21 on Mt. Born near Olten (see above) and with a section as drawn by Moesch (1874, pl. 1, lower section) from near Oberbuchsiten east of Balsthal. Ammonites of the Hypselocyclum Chron near Oberbuchsiten were collected by R. Cartier and published by de Loriol (1881). According to de Loriol (1881:113), the ammonites from near Oberbuchsiten that are certainly of the Hypselocyclum Chron are all perisphinctaceans. Mainly bivalves and to a lesser degree gastropods are abundant in the macrofauna of Oberbuchsiten (de Loriol, 1881:3).

Hermatypic corals first appear in section RG 438 near Balsthal about 12 m above the palaeosol. The hermatypic corals near Balsthal are embedded in calcareous oolite (bed no. 58 of section RG 438 in Gygi, 2000a, pl. 44, a biostrome, and bed no. 20 in the unpublished section RG 439, also a biostrome). This is evidence that the biostromes of sections RG 438 and RG 439 and the coeval bioherms that weather out of the cliff below the castle Alt Falkenstein at Innere Klus near Balsthal grew in water less than 10 m deep. The small coral bioherms below the castle can be discerned when looking from the western bank of the Dünnern river to the east. These bioherms are represented in figure 173. They probably grew during the Hypselocyclum Chron to judge from the section by Moesc (1874) and from the ammonites as published by de Loric (1881). No ammonites of this age were found near Balsthal. I can be concluded from figure 173 that the macrofauna collect ed by R. Cartier near Oberbuchsiten is from a water depth tha was not much greater than that near Balsthal at that time.

8.8.2 Olten

The greater part of the macrofauna of the Platynota and c the Hypselocyclum Chron near Olten (section RG 21, M Born) was collected from *in situ*. Some specimens, mainly am monites, were found in rubble after a large-scale blasting. B valves are the main element of the macrofauna (fig. 188B), bu ammonites are quite common. Perisphinctaceans preva among ammonites. A water depth greater than 20 m must b assumed for the macrofauna near Olten to judge from the al sence of hermatypic corals.

8.8.3 Schönenwerd, Möriken and Villigen

Only perisphinctacean ammonites of the Hypselocycl Chron were found in the macrofauna of the glauconitic be no. 47 (lowermost Reuchenette Formation) of section RG at Halden near Schönenwerd southwest of Aarau. A wat depth of about 40 m is likely for the sedimentation of the be (see below). It is to be noted that oncoids with a diameter more than 1 cm are abundant in this bed. The oncoids a documented by the polished slab Gy 498 that was ph tographed by Gygi (1992, fig. 17).

Ammonites also prevail in the macrofauna of the glauconit lower Baden Member (Platynota and Hypselocyclum Chro at locality RG 428 west of Ebnet on the south slope of M Chestenberg near Möriken, Canton Aargau. Seven pe sphinctaceans and four Haplocerataceae (2 *Taramellicer* 2 *Glochiceras*) were found at this locality. The ammonites a there associated with three terebratulid brachiopods, two ga tropods and one bivalve.

Bed no. 121 (Platynota and Hypselocyclum Chron) of secti RG 62 near Villigen, Canton Aargau, the glauconitic low Baden Member, yielded twelve perisphinctacean ammonit and one rhynchonellid brachiopod.

8.8.4 Mellikon

Ammonites prevail in the macrofauna of the Platynota and the Hypselocyclum Chron that were collected mainly from b no. 124 of section RG 70 at Mellikon. They are about 80% the macrofauna (fig. 188A). Perisphinctaceans are most abu dant in the ammonite fauna. Haplocerataceae are fairly abu dant. This is an indication that the water depth near Mellik was greater than near Schönenwerd at that time.

8.8.5 Schaffhausen

Ammonites are most abundant in the macrofauna of Platynota Zone that was excavated from section RG 239 at cality Summerhalde near Schaffhausen (fig. 160). The percentage of ammonites in the macrofauna is there again about 80% like near Mellikon (fig. 188). Perisphinctaceans are near Schaffhausen less common than near Mellikon, but the percentage of Aspidoceratidae among this superfamily is greater near Schaffhausen. Haplocerataceae are more abundant near Schaffhausen than near Mellikon. These facts are evidence that the water was deeper near Schaffhausen than near Mellikon.

9. Results and discussion

9.1 Frame of reference

The 221 numbered, stratigraphic sections measured in detail by the author between 1962 and 1995 are the frame of reference used in this study. Only a small number of the sections was published. A full record of all the sections and excavations is handwritten in the field books by the author (see above).

9.2 Recent marine carbonates from shallow water

Study of Recent reefs and shallow-water carbonate sediments during two stays in Bermuda (Gygi, 1969b, 1975) and during field trips off Florida, in the Bahamas and off Belize that were organized by the Third International Coral Reef Symposium, Miami (Florida, USA), in 1977 gave valuable information about the environment in which the carbonate rocks from shallow-water in the Late Jurassic of northern Switzerland were formed. Mechanical erosion of Recent reefs by waves is thought to be insignificant (Scoffin et al., 1980:502). Bioerosion is much more important. Bioerosion of Recent reefs in Bermuda by scarid fish was studied and quantified by Gygi (1975). The rate of sediment production by fish was found to be relevant, but Ogden (1977, table 2, fig. 2) proved that the rate of bioerosion by the sea urchin *Diadema antillarum* Philippi is much greater than that by fish on coral reefs of the U.S. Virgin Islands. Scoffin et al. (1980:496) confirmed this on coral reefs of Barbados.

9.3 Sedimentology of Late Jurassic rocks in northern Switzerland

Sedimentology of the rocks from which the ammonites figured by the author and collegues since 1966 were collected was studied by Gygi (1969a; 1981; 1992; 2000a). The terrestrial environment could be documented with palaeosols and with thin lignite layers. Stromatolites with fenestrae and dewatering cracks are characteristic of the marginal-marine, upper intertidal zone. Spherical, primarily indurated calcareous oncoids with a diameter of up to several centimeters, are unknown in the Recent marine environment, but they grew in Late Jurassic time in the studied region from very shallow lagoons down to a depth of more than 100 m. Calcareous oolite was found to have been laid down in the Late Jurassic to a depth not greater than 10 m. Accretion of marine iron ooids is known to have occurred at shallow depth of about 10 m in an equivalent of the Liesberg Member, and about 20 m in the Sornetan Member. Most oolitic ironstones were probably formed in a shallow marine environment (Einsele, 2000:252). Iron ooids also occur in the condensed marker bed at the base of the Birmenstorf Member and in the Schellenbrücke Bed below. These thin, widespread beds are coeval with the Liesberg and with the Sornetan Member. It is evident from figure 40 in Gygi (2000a) that the iron ooids in the condensed beds of the epicontinental basin could not possibly be transported into deep water from the shallow-water facies in the northwest. They must have been accreted *in situ* at a depth of as much as 100 m and at a very slow rate. The stromatolites as figured by Gygi (1969a, pl. 1:2) and by Gygi (1992, fig. 30) from thin, iron oolitic beds do not contradict this. The origin of lime mud that is a large part of the volume of the mud-grade sediments in the epicontinental basin was discussed by Gygi (2000a).
Settling of mud-grade particles out of suspension can only occur in quiet water. Accretion of iron ooids at the surface of muddy sediment requires a moderate oscillating current, and growth of spherical oncoids with a diameter of several centimeters on a muddy bottom in shallow water is only possible when the oncoids are rolled by a strong current. These conflicting conditions in one and the same environment were possible for instance in the very shallow lagoon where the oncoids of the Hauptmumienbank Member grew and were finally embedded in a muddy matrix. Storms occurring at intervals rolled the oncoids and stirred up mud, and the muddy matrix of the oncoids could settle from suspension in the meantime. Similar conditions must be assumed for the formation of oolitic ironstones with a muddy matrix that could occur at a depth of as much as 100 m.

9.4 Facies analysis and submarine topography

A typical vertical, shallowing-upward facies succession in a nearshore environment is that in the lower Günsberg Formation near Péry (section RG 307, Gygi, 2000a, pl. 22). Below are coral bioherms (bed no. 160) and above is calcareous oolite (bed no. 162). The upper bedding plane of the oolite is a marly seam with lenses of lignite and tree branches as well as with characean gyrogonites that document a terrestrial environment. The corresponding lateral, isochronous facies succession in the Recent from hermatypic corals to calcareous oolite and then to land is represented in figure 179. A vertical, deepening-upward succession in shallow water is visible in the interior of the St-Ursanne carbonate platform in figure 173: th lagoonal coral patch reefs of the Buix Member that began t grow in a relatively deep lagoon are above the calcareous oolite of the Delémont Member that was sedimented in ver shallow water. The vertical transition from iron-ooid accretio to glauconite formation in the condensed marker bed at th base of the Birmenstorf Member in the epicontinental basin i also evidence of deepening of the water with time when th sedimentation rate was very low. A spectacular deepening-upward succession that evolved at a time when there was mostl nondeposition can now be seen near Veltheim, Canton Aargau, in the road cut of section RG 226 (see above).
When a vertical facies boundary as for instance that betwee iron-oolitic and glauconitic facies coincides at many differe localities with a time plane as it is the case in the condense lowermost bed of the Birmenstorf Member between easte

Canton Solothurn and eastern Canton Aargau, this means that no relief can be recognized on the seafloor, this is to say that the bottom was flat in that area. When the same vertical facies boundary is heterochronous in thin, condensed beds as for instance in succession 1 between Blumberg and Canton Aargau as was documented above, then the seafloor must have been inclined (fig. 187B), and there was a difference in water depth. The lateral transition from the iron-oolitic Schellenbrücke Bed to the coeval, glauconitic Glaukonitsandmergel Bed (Gygi, 1981, fig. 4) was caused by a difference in the depth of deposition. The thick part of the wedge-like Pichoux Formation is adjacent to the coral bioherms at the margin of the St-Ursanne Formation. The distal, thin part of the Pichoux Formation grades laterally into the Birmenstorf Member with ammonites and siliceous sponges. The Pichoux Formation was therefore sedimented on the depostional slope of a ramp (fig. 173, 187B). Such a depositional slope is also documented by the intraformational truncation surface (fig. 182) and by the submarine debris flow above in the upper Effingen Member near Auenstein that was figured by Gygi & Persoz (1986, fig. 2–3).

A flat topography of the seafloor near or about at sea level at the top of the St-Ursanne Formation of succession 1, at the top of the Hauptmumienbank and of the Steinebach Member of succession 2, and at the top of the Balsthal Formation of succession 3, is indicated by the peritidal Vorbourg Member above the St-Ursanne Formation (fig. 178), exposure of the top of the Hauptmumienbank and of the Steinebach Member at many localities (fig. 183, 176), and by the intertidal stromatolite at the base of the Reuchenette Formation near Péry (fig. 184), as well as by the palaeosol above an erosional surface near Balsthal (fig. 175). The top of the proximal part of the carbonate end members of successions 1–3 was then indeed flat, and these units were carbonate *plat*forms. The Pichoux Formation was a carbonate *ramp*. The bathymetric profile of the top of the distal Balsthal Formation and of the Villigen Formation in Canton Aargau and in Canton Schaffhausen is complicated. It is not understood how the flat terrace of the Villigen Formation in Canton Aargau was formed. Such a terrace existed already before in the Gerstenhübel Beds in the lower Effingen Member (fig. 173).

Facies analysis (Gygi, 2000a) combined with detailed time correlations (Gygi & Persoz, 1986, pl. 1) and with exact and averaged sediment thicknesses gives reliable information of the submarine topography, of the geometry of sedimentary bodies (fig. 173), of water depth and of synsedimentary tectonics (fig. 187) that are discussed below.

9.5 Lithostratigraphy

The "International Stratigraphic Guide", second edition, edited by Salvador (1994), defines stratigraphy on page 13 to be "the organization of rock bodies into distinctive, useful, mappable units based on their inherent properties". The guide continues on page 31 that "lithostratigraphic units are the basic units of geologic mapping". They are "defined and characterized on the basis of their observable, lithologic properties". It says on page 33 that "the formation is the primary formal unit of lithostratigraphic classification", and on page 34 that "the thickness of units of formation rank ... may range from less than a meter to several thousand meters, depending on the size of units required to interpret the lithologic development of a region".

The formation as basic unit of lithostratigraphy was introduced to Switzerland by Thalmann (1966) following the rules of the Code of Stratigraphic Nomenclature by the American Commission on Stratigraphic Nomenclature (1961). The names of members and beds included in the formations as defined by Gygi (1969a) were those coined by Moesch (1863), Würtenberger & Würtenberger (1866) and by Moesch (1867). These old lithostratigraphic names are unequivocal and can be used, with minor revisions, to the present day. In later publications, Gygi followed the International Stratigraphic Guide edited by Hedberg (1976). Therefore, some names, and in one case the rank of a lithostratigraphic unit, were changed by Gygi after 1976. The final version of the scheme of lithostratigraphic units that were conceived by the author was represented by Gygi (2000a, fig. 39). An alphabetic index of lithostratigraphic names that are recommended for use in northern Switzerland for sediments of Late Jurassic age was published by Gygi (2000b). All of this work aimed at providing for lithostratigraphic units that are easy to recognize in sections and are easy to map.

Formations are used here to distinguish for instance a mainly argillaceous succession like the Bärschwil Formation from the pure limestone succession of the St-Ursanne Formation above. The Vellerat Formation above the St-Ursanne Formation is characterized by the complicated vertical variation between limestones and marls. Limestone formations of equal age can be distinguished by their dissimilar lithology: calcareous oolite is the principal facies of the Balsthal Formation, and micrite is typical of the adjacent, more proximal Courgenay Formation (fig. 173). The Courgenay Formation can be subdivided into the well-bedded, well-cemented limestone of the La May Member below and into the massive, partly porous limestone of the Porrentruy Member above.

Allostratigraphic units like the alloformation were introduced into the geologic literature by the North American Commission on Stratigraphic Nomenclature (1983). It is evident from figure 7 of this paper that one of the purposes was to classify alluvial and lacustrine deposits in a graben. Figure 9B of the paper illustrates that discontinuous terrace deposits of gravel on the sides of a valley are meant to be allostratigraphic units. An example of this in northern Switzerland is then for instance the Jüngerer Deckenschotter of Pleistocene age. Burkhalter (1996:877) introduced the alloformation into the geologic literature of Switzerland. His Passwang Alloformation is a marine, epicontinental succession of limestones and marls of Middle Jurassic age in the Jura Mountains. Burkhalter conceived his alloformation in terms of sequence stratigraphy. Sequence stratigraphy is in the present study kept separate from lithostratigraphy for reasons given below. Consequently, the formation in the sense of the International Stratigraphic Guide, second edition by Salvador (1994:33), is further adhered to in this study.

The formations and the units of lower rank that were used by Gygi (2000a; 2000b) are based on a great number of detailed sections that were measured in all of northern Switzerland and beyond. Nevertheless, some difficulties remain. The Liesberg Member at the type locality (section RG 306, pl. 31 in Gygi, 2000a) is a marl with calcareous nodules and with two thin limestone intercalations. The predominantly argillaceous member is therefore assigned to the marly Bärschwil Formation. At other localities, the Liesberg Member is transitional between the marl of the Bärschwil Formation below and the pure limestone succession of the St-Ursanne Formation above, like in the sections RG 373 and 389 near Vellerat (Gygi, 2000a, pl. 24) and in the well-known section RG 399 (Gygi, 2000a, pl. 34) of the landslide west of Vögeli farm near Bärschwil, Canton Solothurn. This landslide is the "Fringeli" of former authors and is represented, but unnamed on the Swiss topographical map (Landeskarte) 1:25000, sheet 1086 Delémont.

The Günsberg Formation represents a narrow carbonate platform between the calcareous Vorbourg Member and the more argillaceous Röschenz Member in the proximal direction, and the predominantly marly, distal Effingen Member in the epicontinental basin. The Günsberg Formation was formerly interpreted to be the lowermost member of the Balsthal Formation, because the two formations are difficult to distinguish in section RG 384 in Lochbach gorge near Selzach (Gygi, 2000a, pl. 29) and elsewhere in the Weissenstein range.

Moesch (1867) was right to distinguish the Wangen Member from the Letzi Member in Canton Aargau, because the thin Knollen Bed between these members later proved to be an excellent regional marker bed that can be followed from Schönenwerd west of Aarau to Canton Schaffhausen (Gygi, 1969a). The bed marks in Klettgau and in the Randen of Canton Schaffhausen the boundary between the Küssaburg Member and the Wangental Member of Würtenberger & Würtenberger (1866). The Knollen Bed is important because according to current knowledge, its base is more or less coeva with the time plane that represents the base of the Kimmerid gian Stage (Gygi, 2000a, fig. 40). The Knollen Bed is above se quence boundary O8 of Gygi et al. (1998, fig. 12). It is litho logically not characteristic enough and too thin to b mappable. Therefore, the limestone units below and abov cannot be distinguished when mapping and have to be com bined. This was done both by Mühlberg (1904) and by Schalc (1916) on their geologic maps of Canton Aargau and of Ca ton Schaffhausen, respectively.

Lithostratigraphy should be kept separate from sequen stratigraphy for the following reasons: Sequence boundary C of Gygi et al. (1998, fig. 3) coincides with the mineral-strat graphic correlation J by Gygi & Persoz (1986, pl. 1A). The s quence boundary could not be recognized in section RG 4 near Balsthal (Gygi, 2000a, pl. 44). In section RG 307 ne Péry (Gygi, 2000a, pl. 22), sequence boundary O8 is thoug to be far below a conspicuous, probably subaerial erosion su face above bed no. 232 of the section. The erosion surface h some relief. Above the surface are blackened lithoclasts wit diameter of up to 12 cm (base of bed no. 233, fig. 186). On M Chamben near Balm, Canton Solothurn, there is an intertic stromatolite with wavy lamination about at the same level the blackened lithoclasts near Péry. The stromatolite on M Chamben is within the upper Holzflue Member (coordina ca. 609930/235840/1220). This stromatolite and the bed w black pebbles near Péry are probably coeval and possibly the same age as the base of the Porrentruy Member of

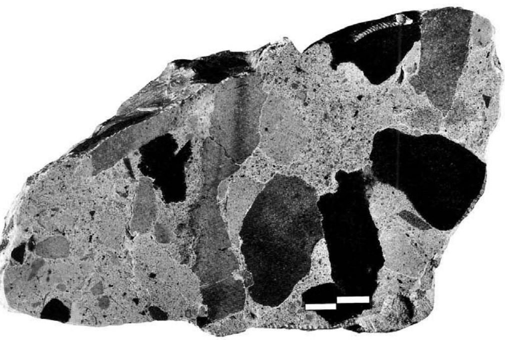


Fig. 186. Blackened lithoclasts above an erosional surface.
Polished slab Gy 3484 from the lower part of bed no. 233 in the Verena Member of section RG 307 near Péry, Canton Bern (Gygi 2000a, pl. 22). Scale bar is 2 cm.

Courgenay Formation in section RG 350 near Courgenay, Canton Jura (Gygi, 2000a, pl. 19). Sequence boundary O8 can be discerned neither in section RG 350 that is the type section of the Courgenay Formation, nor in the type section RG 438 of the Balsthal Formation near Balsthal.
The boundary between the St-Ursanne Formation and the Vellerat Formation as defined by Bolliger & Burri (1970:70), that was adopted by Gygi et al. (1998, fig. 2), is transitional in the type section of the St-Ursanne Formation at St-Ursanne (Gygi, 2000a, fig. 33). Both the massive Buix Member of the upper St-Ursanne Formation below and the bedded Vorbourg Member of the lower Vellerat Formation above are pure limestones. The bounding surfaces that delimit the individual beds within the Vorbourg Member are hardly visible in the lowermost part of the member and only become gradually more distinct upward in the succession. Distinct bedding is the principal difference between the massive limestone of the Buix Member below and the bedded Vorbourg Member above. Diastems therefore can not normally be used to define a formation boundary like that between the St-Ursanne Formation and the Vellerat Formation.
A related problem is the delimitation of the coeval Courgenay, Balsthal and Villigen Formation from the Reuchenette Formation above and its time equivalents in the epicontinental basin. The mineral correlation L by Gygi & Persoz (1986, pl. 1B) was calibrated in section RG 70 near Mellikon with ammonites to coincide with the boundary between the Planula and the Platynota Zone. The zonal index of the Planula Zone is *Subnebrodites planula* (Quenstedt) that was figured by Gygi (2000a, pl. 11:5) from the unpublished section RG 84 near Hemmenthal in Canton Schaffhausen. The zone is represented in section RG 70 near Mellikon by *Subnebrodites laxevolutus* (Fontannes) that was figured by Gygi (2000a, pl. 11:4). The Platynota Zone above begins in section RG 70 with *Sutneria (Sutneria) platynota* (Reinecke) morphotype A Schairer (fig. 159a in this study). The Platynota Zone is probably very thin in this section. A better specimen of the taxon *platynota* A was figured by Gygi (2000a, pl. 13:2) from section RG 239 at Summerhalde near Schaffhausen (fig. 160). The top of the Villigen Formation in the uncondensed section RG 239 is the top of bed no. 17. The top of the Planula Zone is within bed no. 20 of the section where the last *Sutneria (Sutneria) galar* (Oppel) occur, and where the first *Sutneria (Sutneria) platynota* (Reinecke) A were found. The lithostratigraphic boundary between the Villigen Formation and the Schwarzbach Formation near Schaffhausen therefore almost coincides with the biostratigraphic boundary between the Planula and the Platynota Zone.
The mappable boundary between the Villigen Formation and the Schwarzbach Formation in Canton Schaffhausen, between the Villigen Formation and the Baden Member in Canton Aargau (Gygi, 1969a, pl. 17, sections RG 62 and 70) and between the Balsthal Formation and the Reuchenette Formation near Péry (section RG 307, Gygi, 2000a, pl. 22) that is conspicuous near Undervelier, Canton Jura, as represented by Gygi (2000a, fig. 38), can be assumed to be about coeval with the boundary between the Planula and the Platynota Zone. The same is probably the case in the type section of the Courgenay Formation, RG 350 in plate 19 of Gygi (2000a), where the Reuchenette Formation begins with bed no. 80.
The upper boundary of the Courgenay, the Balsthal and the Villigen Formation that can be correlated lithostratigraphically over most of northern Switzerland with the exception of the region of Balsthal, was interpreted by Gygi et al. (1998, fig. 5–6) to be a maximum flooding surface. Sequence boundary K 1 above may be coeval with the mineral correlation L by Gygi & Persoz (1986, fig. 9, compare with several pertinent plates in Gygi, 2000a). The upper boundary of the Balsthal Formation in the type section RG 438 in Steinebach gorge near Balsthal (Gygi, 2000a, pl. 44) is now recommended to be drawn at the base of bed no. 52, a palaeosol, that probably corresponds to sequence boundary K 1.

9.6 Taxonomy of ammonites

Ammonite taxonomy is fundamental to time correlations as were made by Gygi & Persoz (1986, pl. 1) and by Gygi (2000a, fig. 39). Taxonomy of Late Jurassic ammonites in the region was studied in several papers by the author and by ammonite specialists cooperating with him. These publications are listed in Gygi (2000a) and in this study. Perisphinctaceans are particularly useful for time correlations, because some of their taxa could live both in very shallow water and at the greatest depth that occurred in the studied part of the Rhodano-Swabian, epicontinental basin. Zonation of the Kimmeridgian in northern Switzerland depends exclusively on perisphinctaceans.
Recognition of biologic species in ammonites corresponding to species in neozoology would have been interesting, but the author never aimed at this. Instead, the present taxonomic study of perisphinctaceans was made like the previous studies in ammonite taxonomy in order to provide clearly defined morphospecies that can be used in biostratigraphy. 57 formal perisphinctacean taxa on the species level are here described and figured. 53 of these are figured for the first time from Swiss localities. Five taxa are new to science.
The importance of the new ammonite material that was found in northern Switzerland is that it includes very large and even some giant specimens. *Involuticeras*, *Balticeras* and *Pachypictonia* can only be identified and distinguished when nearly complete specimens of these large-size genera are at hand. The holotype of *Balticeras pommerania* Dohm is a wholly septate nucleus. The diameter of it is but 198 mm. This was for a long time the only well-preserved representative of the taxon, and it was exclusively known from Czarnoglowy, Poland. Now, 13 specimens of the taxon with diameters varying between small nucleuses and giants from northern Switzerland could be studied, including a nearly complete adult. The different growth stages of the taxon and the size of adults could be recognized for the first time thanks to this material.
The new material from Switzerland documents that typical *Ringsteadia* and *Balticeras* are not coeval as was presumed by Arkell in Arkell et al. (1957:L324). Moreover, it is now certain that *Balticeras* is not a subgenus of *Ringsteadia*. Instead, *Balticeras* seems to be closely related with *Involuticeras* and mainly with *Pachypictonia*. No taxa of *Ringsteadia* occurring in northwestern Europe are also found in central Europe. There was a pronounced provincialism in taxa of *Ringsteadia* during the Late Oxfordian. *Ringsteadia suebica* Gygi in Gygi (2000a:96, pl. 12:1) is maybe somewhat younger than the last representatives of the genus in northwestern Europe. It is as yet uncertain whether *Ringsteadia*? cf. *weinlandi* (Fischer) that

is possibly from the Platynota Zone (fig. 144) can be assigned to the genus *Ringsteadia*.

9.7 Biostratigraphy of ammonites

An overview of ammonite biostratigraphy in the Oxfordian and in the Early Kimmeridgian in northern Switzerland was given by Gygi (2000a, fig. 61). The Platynota and the Hypselocyclum Zone were then not subdivided. *Idoceras hararinum* Venzo J 24356, here represented in figure 97, was misidentified as *Idoceras balderum* (Oppel) by Gygi (2000a). Because of this error, it was then indicated that *Idoceras balderum* (Oppel) and *Pseudhimalayites uhlandi* (Oppel) succeed each other in time.
Schairer (1970) discerned in Franconia, southern Germany, three morphotypes in *Sutneria platynota* (Reinecke) that he called A, B and C. These morphotypes succeed each other in time. Numerous representatives of morphotypes A and C were found in excavation RG 239 at Summerhalde near Schaffhausen (fig. 160). The gap between the vertical ranges of the morphotypes A and C is apparently about equivalent to the vertical range of morphotype B in Franconia. Only morphotype A occurs in Canton Aargau (fig. 159a, see also Gygi, 1969a, pl. 17, section RG 70, bed no. 120). This statement can be taken for granted, because hundreds of ammonites were collected both from the lower Schwarzbach Formation in excavation RG 239 near Schaffhausen and from the lower Baden Member in section RG 70 near Mellikon. Presence or absence of representatives of the three morphotypes of *Sutneria platynota* (Reinecke) therefore varies between Franconia in southern Germany, Schaffhausen and Mellikon in northern Switzerland.
In the present study, all zones and subzones of the Oxfordian and of the Early Kimmeridgian could be documented with ammonites that were found in northern Switzerland. The corresponding ammonites, number 1–34, are listed in figure 174, together with their biostratigraphic position. All of these ammonites were figured in papers by the author and co-authors that were published since 1977. The references of the papers are given in figure 174. The authors of the zones and subzones represented in figure 174 that are currently used in the Late Oxfordian and in the Early Kimmeridgian and the names of the corresponding index ammonites are given above in chapter 4 on biostratigraphy.

9.8 Mineral stratigraphy

The first step in mineral stratigraphy that was taken by Gygi & Persoz (1986) was to sample sections RG 37 and RG 226 at Auenstein/Veltheim (base of Birmenstorf to base of Geissberg Member), RG 294 in Gabechopf quarry near Villigen (base of Geissberg Member to Crenularis Member) and RG 70 in the large quarry near Mellikon (top of Geissberg Member to lower Wettingen Member) at the intervals indicated by dashes in figure 10, composite section "Aargau", by Gygi & Persoz (1986). The section "Aargau" in figure 10 was assembled from sections that were measured in detail in sediments from deeper water of an epicontinental sea. There are ammonites in all of these sediments that could therefore be dated biostratigraphically (Gygi & Persoz, 1986, table 3). The partial sections mentioned above were assembled according to the ammonites within them.
Then more sections in coeval sediments further to the west were sampled that include facies of the bottom of the epicontinental basin, the slope, of very shallow water and even of the supratidal, terrestrial environment. Clay minerals and detrital quartz were identified and their percentages measured. The clay mineral kaolinite was found to be essentially of detrital origin. Kaolinite occurs in quantities sufficient for X-ray analysis even in cleanly washed calcareous oolite. This and the fact that the mineral occurs in sediments from land to marine deposits of an epicontinental basin was used for time correlations. Correlations were possible, because there is a pronounced vertical variation in the abundance of kaolinite in the analyzed sections.
The vertical succession of highs and lows of kaolinite content in a section was first calibrated with biostratigraphy based on ammonites in the basin. Then this curve of kaolinite abundance was correlated with corresponding maxima and minima of the mineral in the proximal direction. This was done in combination with a revised, detailed lithostratigraphy. The resulting time correlations could be checked and confirmed by several ammonites that were found in proximal, shallow-water sediments. Additional ammonites from shallow water that were figured by Gygi (1995) are recorded in figure 173 of the present study. They corroborate the time correlations made by Gygi & Persoz (1986).

9.9 Relative sea-level changes

A major relative sea-level rise occurred during deposition of succession 1 between Canton Schaffhausen and Péry in Canton Bern. This is concluded from the vertical transition between iron-ooid accretion below and the formation of mature glauconite pellets above that first occurred at the beginning of the Late Jurassic in relatively deep water near Blumberg north of Canton Schaffhausen (fig. 187A). Then, the same vertical facies transition happened at the beginning of the Antecedens Subchron where the water was initially shallower in Canton Aargau or in eastern Canton Solothurn. Probably a little later in the Antecedens Subchron and in even somewhat shallower water, mature glauconite pellets began to be formed in the lowermost Pichoux Formation near Péry (see above). The rise cannot be quantified in the studied region.
Part of this rise was a rapid and substantial pulse of sea-level rise that occurred during the Cordatum Subchron. This is documented by the fossil bed about in the middle of the distal part of the Sornetan Member. Most of the macrofossils in this marker bed are ammonites that were figured by Gygi & Marchand (1993). This is evidence of a water depth of probably at least 30 m (see below). The high concentration of macrofossils in this bed is evidence that the bed was sedimented at a low rate. Gygi (1986:474) interpreted this sea-level rise to be eustatic, because he had reason to believe that the sea-level rise as described here from Switzerland corresponds to that observed and estimated at about 10 m by Talbot (1973:313), a great distance away in southern England.
Another rapid sea-level rise during deposition of succession 1 occurred later, in the late Antecedens Subchron. A conspicuous effect of this was the abrupt termination of accretion of

calcareous ooids at the top of the Delémont Member in the St-Ursanne Formation near St-Ursanne that was followed by the growth of luxuriant coral reefs in the lagoon of the Buix Member above that was created by the process (Gygi, 1986, fig. 5). This was caused a major eustatic event (Gygi, 1986:473), because Arkell (1947:99) dated the base of the Coral Rag in southern England at the same time. Talbot (1973, table 2) and Wilson (1968, fig. 7B) recorded the event in other regions of southern England. The rise must be what Enay (1966:284) called "transgression argovienne", and the effect of it "discordance antéargovienne" (op.cit., fig. 76).
The effect of a rapid sea-level rise during deposition of succession 2 is clearly visible in the quarry of La Charuque near Péry, Canton Bern (fig. 181). This occurred during the Hypselum Subchron, prior to the deposition of the Hauptmumienbank Member. The rise created accommodation space of several meters for a tidal delta at this locality, and elsewhere sufficient depth and circulation of the water for growth of hermatypic corals even far in the proximal direction from the basinward margin of the Günsberg carbonate platform, near Bressaucourt, Canton Jura. Hermatypic corals also occur below the Hauptmumienbank Member in beds no. 39 and 41 of section RG 381 in Court gorge near Moutier (Gygi, 2000a, pl. 28), or in the marly bed no. 59 in the unpublished section RG 312 near Souboz, Canton Bern. Coeval is bed no. 55 with corals in section RG 406 near Vermes, Canton Jura (Gygi, 2000a, pl. 37), and bed no. 38 of the unpublished section RG 414 near Grandval with the giant nautiloid *Paracenoceras ingens* Tintant et al. (2002) J 30716. Cross-bedded calcarenite filled this rapidly created accommodation space elsewhere (Gygi & Persoz, 1987, fig. 2A; Gygi, 2000a, pl. 28, section RG 381, bed no. 38).
The fact that this transgression of marine facies over pertidal and even over supratidal sediments can be followed from Péry, Canton Bern, over a palinspastic distance of much more than 30 km to Bressaucourt near Porrentruy, led Gygi (1986:467) to the conclusion that the transgression was the effect of a minor eustatic sea-level rise in Hypselum time.
The lower part of the coral limestone of the Olten Member that is mostly a biostrome of hermatypic corals, grades laterally into the thickly-bedded, micritic Geissberg Member (fig. 173). There are no hermatypic corals in the Geissberg Member. Bivalves are the main element of the macrofauna in this unit, and there are few perisphinctacean ammonites. The depth of deposition of the Geissberg Member east of Olten must therefore have been greater than about 20 m. Above the Geissberg Member in Canton Aargau is the thin, glauconitic Crenularis Member. Glauconite in this member is evidence of a low sedimentation rate. Glauconite was also recorded by Gygi (1969a, pl. 18) in bed no. 32 of section RG 21 near Olten in the lower Olten Member. These glauconitic beds are probably coeval and were sedimented at a reduced rate during a eustatic sea-level rise that occurred in the Bimammatum Subchron (Gygi, 1986, fig. 4), above the transgressive surface indicated in figure 2 by Gygi et al. (1998).
Growth of corals in the Olten Member finally ceased some time during the Planula Subchron (fig. 173). The demise of coral growth probably occurred when the water became deeper than about 20 m, and coral growth could not keep up with the relative sea-level rise. It must be noted that the rapid relative sea-level rise that occurred earlier, at the end of the Bimammatum Chron (Gygi, 1986, fig. 4), did not interrupt coral growth in the Olten Member. Further east, in the Villigen Formation, the rapid rise led to a significant reduction of the rate of sedimentation of the Knollen Bed. This is a marker bed that can be followed from Schönenwerd east of Olten to southern Germany north of Canton Schaffhausen (Gygi et al., 1998, fig. 2, 12). The base of the Knollen Bed is sequence boundary O8 of Gygi et al. (1998) that is conspicuous in section RG 62, top of bed no. 58 near Villigen (Gygi, 1969a, pl. 17; Gygi et al., 1998, fig. 2). Sequence boundary O8 coincides with the mineral stratigraphic correlation J of Gygi & Persoz (1986, pl. 1A). It can be read from figure 187C–D that the water depth increased during deposition of succession 3 between Balsthal and eastern Canton Aargau. This process began already during sedimentation of the uppermost part of succession 2 where bivalves prevail in the macrofauna of the Geissberg Member. It continued to the Hypselocyclum Chron, because ammonites prevail in the macrofauna of the lower Baden Member of Canton Aargau. Ammonites are quite common in the lower Reuchenette Formation of section RG 21 near Olten (fig. 188B). Evidence is given below that only part of this relative sea-level rise was eustatic.
Relative sea-level falls are documented by the palaeosols with calcite rays above calcareous oolite at the top of the Steinebach Member (fig. 176) and at the top of the Balsthal Formation (fig. 175). The sea-level fall that occurred after the end of deposition of the oolite shoal of the Steinebach Member must have been of the order of several meters, because it was sufficient to expose parts of the floor of the adjacent, shallow lagoon in which the coeval Hauptmumienbank was sedimented (fig. 183). Another such event can be concluded of the hardgrounds that were bored after a transgression in the Günsberg Formation near Vermes, Canton Jura (fig. 5 in Gygi & Persoz, 1986, see also pl. 34, section RG 406, bed no. 49 in Gygi, 2000a), and near Moutier (section RG 381, top of bed no. 28, pl. 28 in Gygi, 2000a). The upper surface of bed no. 28 of section RG 381 in Court gorge is bored, encrusted with ostreids, and is covered by a limonitic crust. This is sequence boundary O6 of Gygi et al. (1998, fig. 7). The surface can no more be seen in the section on the western side of the cantonal highway through Court gorge. The bedding plane is now only visible as a small, weathered surface on the southeastern side of the road above the Birs river. Probably coeval with the bored hardground mentioned from Court gorge above bed no. 28 are the stromatolite with prism cracks of bed no. 42 in the unpublished section RG 417 near Crémines, Canton Bern (fig. 177), and the prism-cracked stromatolite of bed no. 21 in the unpublished section RG 414 near Grandval, Canton Bern (Gygi, 1992, fig. 6).
Data from sections measured in northern Switzerland and in southern England suggest that eustatic sea-level *rises* plus basement subsidence caused by the additional water load could amount to relative sea-level rises of as much as about 10 m per sequence in Oxfordian time (Gygi, 1986, sea-level curve in fig. 4, and other authors cited therein). According to the present study, sea-level *falls* were less than 10 m per sequence at that time. Sahagian et al. (1996, fig. 12) thought that eustatic sea-level fluctuations of several tens of meters, and especially eustatic sea-level falls of as much as about 30 m occurred during the Oxfordian over the Russian Platform. Their much greater estimates of fluctuation are not substantiated with ev-

idence from sections that were measured and dated in detail. Eustatism during the Pleistocene was much greater that that in Late Jurassic time. According to Bard et al. (1990), a Recent coral reef was drilled and cored off Barbados in the tropical West Atlantic. The deepest sample with the coral *Acropora palmata* was from a depth of 118 m. This depth was calculated using a linear uplift correction for the island of Barbados. *Acropora palmata* grows on Recent reefs only in very shallow water. The age of the sample with this coral was measured with the U-Th method to be roughly 19000 years. The last glaciation of the Pleistocene was at its peak at that time. Lambeck & Chappell (2001, fig. 1B) calculated a sea-level rise of between 120 and 130 m to have occurred since the peak of the last Pleistocene glaciation off Huon Peninsula in Papua New Guinea. Eustatically controlled sea-level fluctuations during the Late Jurassic are likely to have been less than one tenth of those that are now known to have occurred during the Pleistocene.

9.10 Sequence stratigraphy

P.R. Vail and A.L. Coe interpreted the sections that were measured before by R. Gygi in terms of sequence stratigraphy during two field trips of several days and in the office at Basel. They found that sequence boundaries are the most laterally widespread surfaces in the studied successions, and they could identify all of the sequence boundaries that are currently discerned in coeval sediments elsewhere in Europe. The result was published by Gygi et al. (1998).

9.11 Magnetostratigraphy

The fine-grained, uncondensed sediments of the whole of the Oxfordian and of the Early Kimmeridgian in northern Switzerland were systematically sampled for magnetostratigraphy by J. Ogg from the USA. His results were unsatisfactory and were therefore not published.

9.12 Radiochronology (numerical ages)

Radiometric ages of glauconites from the late Early Oxfordian Glaukonitsandmergel Bed in Canton Schaffhausen and from the lower Baden Member of the Early Kimmeridgian in Canton Aargau were measured by Gygi & McDowell (1970, table 1) with the potassium-argon method. Fischer in Fischer & Gygi (1989) measured glauconites from different beds of section RG 81b near Gächlingen, Canton Schaffhausen. The analyzed glauconite pellets of section RG 81b are from the Glaukonitsandmergel Bed, the Mumienmergel Bed and from the unnamed, thin glauconitic marl above the Mumienkalk Bed. In all of these beds are abundant ammonites that were excavated by R. and S. Gygi. The age of the ammonites ranges from the Cordatum Subchron to the Luciaeformis Subchron.
Glauconite pellets as were dated by Fischer & Gygi (1989) occur both within calcareous ammonite steinkerns and in the embedding marl. The glauconites are authigenic and were probably formed at the same time within the ammonite steinkerns as in the embedding, argillaceous sediment. Therefore, the analyzed glauconites were expected to have the potential to assign numerical ages directly to the ammonites that were figured in the same paper. A correlation of ammonite biostratigraphy with radiochronology was addressed. The three measured numerical ages were of the right order in time, but they were later found to be all about 6% younger than the corresponding ages given in the timescale by Gradstein et al. (1995) that figure 185 of this study is based on. The reason why the ages measured in northern Switzerland are too young is probably that the potassium content of the measured glauconite pellets is relatively low (Gygi & McDowell, 1970, table 1). The lattice order of the individual glauconite crystals depends on their potassium content. Glauconites with a high potassium content have a well-ordered lattice, whereas the lattice of glauconite crystals with less potassium has a lesser degree of order.
It can be read from the X-ray diffractogram represented in figure 3A by Gygi & McDowell (1970) that the crystal lattice of the measured glauconites is not well-ordered. It is probable that the imperfect lattice order is the reason for the incomplete retention of argon, a gas, in the crystals. Ar 40 is the product of nuclear decay of K 40. The ages calculated from the analysis of the content of potassium and argon in the crystals are therefore probably too young. This is evident when the ages as measured by Fischer in Fischer & Gygi (1989) are compared for instance with the 158 million years of the Cordatum Subchron in figure 185 of this study.

9.13 Time correlation

Time correlation of the studied sediments is difficult because of the occurrence of nondeposition, condensation, and because of great variation in "normal" sedimentation rates. Detailed time correlation of the studied sediments is impossible using a single method. This is apparent when the widely varying correlations made by previous authors are compared in figure 3 by Gygi (2000a). There were long periods of nondeposition without exposure that left no conspicuous traces in the succession. An example of this is the hiatus in the core as figured by Gygi (1969a, pl. 2:4) at the base of the Oxfordian sediments near Veltheim, Canton Aargau, that represents a time span of about seven million years (see below). On the other hand, shallow marine sedimentation ceased and was followed by subaerial erosion during the Platynota Chron near Balsthal, Canton Solothurn. Erosion produced a substantial relief at the top of the Balsthal Formation that can be recognized from a distance of more than 2 km (fig. 37 in Gygi, 2000a). A palaeosol was formed above the erosional surface (fig. 175). Shallow marine sedimentation resumed after only a fraction of the Platynota Chron. Nevertheless, the break in marine sedimentation is conspicuous in the succession.
There are thin and condensed beds that can be followed over long distances. The thickness of the whole succession 1 is less than 1 m in Canton Schaffhausen and grows to a compacted average of 185 m in northwestern Switzerland. Concomitant with the great differences in thickness are pronounced vertical and lateral facies changes. Detailed time correlation of sediments of Late Jurassic age in northern Switzerland became possible only when a *combination* of refined lithostratigraphy, biostratigraphy with ammonites, mineral stratigraphy and sequence stratigraphy was used.

9.14 Rates of sedimentation

The rates of sedimentation of the studied marine strata were very variable and could even be negative in the deep subtidal zone. At times of nondeposition, existing calcareous sediment at the seafloor could be removed by submarine corrosion that Heim (1958:643) called subsolution. At the base of section RG 210 in the cleft of Eisengraben near Gansingen, Canton Aargau (Gygi, 1977, pl. 11, section no. 4), there is a succession of bedded, tough limestone with some detrital quartz that is dated with an ammonite to be of Early Callovian age (beds no. 4–6, see Gygi, 1977:443). This is the time equivalent of the Kornberg sandstone Member below the iron ore in the former mine near Herznach. Above the sandy limestone near Gansingen is a condensed iron oolite including ammonites from the Middle Callovian to the Early Oxfordian. Cobble-like nodules of the sandy limestone below that are embedded in the iron oolite above are probably the result of subsolution that occurred before deposition of the iron oolite began. Subsolution began in Canton Schaffhausen at the end of the Middle Callovian after deposition of the iron-oolitic limestone in the uppermost Herznach Formation. The resulting submarine, erosional surface is hummocky in excavation RG 81b near Gächlingen. The top of bed no. 10 of the excavation has a relief of as much as 20 cm (Gygi, 1977, pl. 11, section no. 6). Then followed a time of nondeposition *without* exposure that lasted more than two million years (as read from chart no. 7 by Hardenbol et al. in de Graciansky et al. 1998). Sedimentation resumed only in the Cordatum Subchron of the Early Oxfordian with deposition of the thin Glaukonitsandmergel Bed.

The drill-core mentioned above of the Middle/Upper Jurassic boundary beds as figured by Gygi (1969a, pl. 2:4) from near Veltheim, Canton Aargau, is evidence that nondeposition in a shallow-marine environment could last a very long time without intervening exposure. The break in sedimentation between the end of deposition of the thin bed of iron oolite that was then labelled "eisenoolithischer Kalk, untere Oxford-Stufe" (now known to be of Middle Bathonian age) and formation of the chamositic crust on top of the iron oolite (crust visible only on the left side of the core represented in the figure) lasted about seven million years. There is no evidence of exposure during this time. On the contrary, water depth increased during the time of nondeposition. According to paragraph 8.1.5 above, sedimentation of the iron oolite ceased late in the Middle Bathonian, and recommenced only in the Middle Oxfordian when the condensed bed at the base of the Birmenstorf Member was laid down above the chamositic crust.

There is no sedimentologic evidence of a break in sedimentation in section RG 307 near Péry, Canton Bern (Gygi, 2000a, pl. 22), between the top of the Renggeri Member (bed no. 21) and the base of the Pichoux Formation (bed no. 22). Nevertheless, a hiatus representing the time of three ammonite subchrons or nearly one million years is indicated by ammonites found below and above the intervening bedding plane: *Cardioceras (Scarburgiceras)* cf. *reesidei* Maire J 27992 of the Bukowskii Subchron from bed no. 21 below as figured by Gygi (1990b, pl. 6:3), and *Perisphinctes (Dichotomosphinctes) antecedens* Salfeld J 27994 of the Antecedens Subchron from bed no. 22 above the hiatus (op.cit., pl. 5:4). Exposure can be ruled out to be the cause of the hiatus, because ammonites prevail in the macrofauna both of the Renggeri Member below the hiatus and in the macrofauna at the base of the Pichoux Formation above.

The sedimentation rate was very low when the condensed marker bed at the base of the Birmenstorf Member was laid down in Canton Aargau during the Densiplicatum and the Antecedens Subchron. An average thickness of less than 10 cm of lime mud was then laid down during about 600 000 years. At the same time, the upper part of the Sornetan Member, the Liesberg Member and the greater part of the St-Ursanne Formation were deposited in northwestern Switzerland. The aggregate and compacted, averaged thickness of these sediments in northwestern Switzerland is roughly 80 m as compared with the mean thickness of about 8 cm of the coeval, condensed bed at the base of the Birmenstorf Member in Canton Aargau. The sedimentation rate then varied at the scale of 1000:1 between the two regions at that time.

A high average rate of sedimentation of up to more than 3 m per 10000 years was calculated by Gygi (1999, fig. 2) for the deposition of the predominantly argillaceous Effingen Member in Canton Solothurn and in Canton Aargau. Late Jurassic carbonate platforms of the region were formed at a lower average rate: 1.2 m per 10 000 years was calculated for the St-Ursanne Formation, and 0.7 m per 10 000 years for the Laufen and for the Verena Member of the Balsthal Formation. A deep exploration well was drilled on Andros Island in the Bahamas between April 1946 and April 1947 to a depth of 14585 feet. The bottom of the hole was within the Lower Cretaceous (Spencer, 1967:263 and fig. 1). The well penetrated carbonates and some sulfate evaporites (op.cit., fig. 2). Newell & Rigby (1957:64) calculated an average sedimentation rate for this well of 0.36 m per 10000 years.

Succession 1 is shallowing-upward in northwestern Switzerland. Argillaceous mud supplied from land in the north-northwest began to fill the marginal part of an epicontinental basin that had an original depth of about 70 m (see below). Deposition of the argillaceous mud bank of the Bärschwil Formation proceeded at a normal rate and ended on a flat surface at a water depth of about 10 m. The average sedimentation rate was greater than the mean rate of relative sea-level rise (fig. 187 B). But the fossil bed in the middle of the distal part of the Sornetan Member with its abundant macrofauna of mostly ammonites indicates that the sedimentation rate of the thin bed was low. Evidence was presented by Gygi & Marchand (1993:1006) that the bed was laid down above a transgressive surface that was the effect of a rapid and substantial eustatic sea-level rise (Gygi, 1986:474 and fig. 4). This rise caused the source of terrigenous mud to recede landward, and this led to the temporarily low sedimentation rate in the distal Sornetan Member. The compacted, average thickness of succession 1 is 185 m in northwestern Switzerland, 370 times thicker than the 0.5 m of the same succession in section RG 81b near Gächlingen in Canton Schaffhausen. Succession 1 is an example of how much the rates of sedimentation varied both *vertically* and *laterally* during the Late Jurassic in northern Switzerland (fig. 187B).

The sedimentation rate of succession 3 in Canton Aargau changed twice from normal to low in the deep subtidal zone. The first time interval with a low sedimentation rate is indicated in the Crenularis Member by fairly abundant glauconite, by partly corroded bedding planes and by a great abundance of the bivalve *Pholadomya* in the lowermost Crenularis Member in the unpublished section RG 63 near Villigen. The member was laid down above the transgressive surface of a eustatic sea-level rise that caused the area of argillaceous mud deposition of the Bure Member to recede far back in the proximal direction. The mud accumulation of the Bure Member was rimmed by the shoal of the predominantly calcareous, but partly ferruginous Oolite rousse Member that is above sequence boundary O7 of Gygi et al. (1998, fig. 2). There is no evidence that argillaceous mud bypassed the sand shoal of the Oolite rousse.

Another eustatic sea-level rise of possibly minor order began at the onset of the Planula Chron (Gygi, 1986, fig. 4). This left no trace in the Olten Member and on the platform in the Holzflue Member of section RG 438 near Balsthal (Gygi, 2000a, pl. 44). Further in the distal direction, the rise is documented by the low sedimentation rate of the thin Knollen Bed above sequence boundary O8 (Gygi et al., 1998, fig. 12). There is some glauconite in the Knollen Bed, but it can be rare. Glauconite, corroded bedding planes and relatively common macrofossils (mainly terebratulid brachiopods in Canton Aargau and mainly ammonites in Canton Schaffhausen) are evidence of a low sedimentation rate of the Knollen Bed. The fact that both the Crenularis Member and the Knollen Bed were sedimented at a low rate during eustatic sea-level rises, and that the Knollen Bed can be followed from Schönenwerd into the epicontinental basin as far as southern Germany north of Canton Schaffhausen, are an indication that the major part of the great quantity of lime mud of the Villigen Formation in the basin was exported from the carbonate platform of the Balsthal Formation.

Most of the lime mud of the Villigen Formation was probably supplied from the proximal, shallow-water realm to the basin like the argillaceous mud of the Sornetan Member. The low sedimentation rates of the fossil bed in the distal part of the Sornetan Member, of the Crenularis Member and of the Knollen Bed are all the effect of rapid, eustatic sea-level rises. These significantly reduced the rate of mud supply and the rate of sedimentation in the deep subtidal zone irrespective of whether the mud was argillaceous, carbonate, or mixed like in the Effingen Member. A substantial part of the marl in the Effingen Member is lime mud. The total carbonate content of the Effingen Member does not increase in the distal direction where the thickness of the member diminishes very much (fig. 173, see also Nagra 2001). This is evidence that most of the lime mud in the Effingen Member, like that in the Villigen Formation above, was supplied from the shallow-water realm. Coccoliths were recorded in the Effingen Member as well as in the Villigen Formation by Gygi (1969a, fig. 1, and pl. 11:41). Gygi (1969:117) concluded that coccoliths in these units are *primarily* rare, not because of diagenetic recrystallization. This was confirmed by Pittet & Strasser (1998) and by Pittet et al. (2000:379).

The problem of the origin of lime mud is as yet unsolved. A relatively deep lagoon was formed in the upper St-Ursanne Formation (Buix Member) because of a eustatic sea-level rise. At the same time, the large amount of lime mud that accumulated in the upper part of the Pichoux Formation was shed mostly into the distal direction from the narrow oolite shoal of the Tiergarten Member. It is improbable that the great quantity of lime mud within the Effingen Member originated by whitings over the narrow carbonate platform of the Günsberg Formation alone. The widespread, but very shallow lagoon in which the Hauptmumienbank Member was laid down evolved when the considerable amount of lime mud of the Geissberg Member was selectively exported basinward from the oolite shoal of the Steinebach Member. It is inconceivable that the great amount of lime mud in southern Germany that is time-equivalent with the upper Villigen Formation in Switzerland was all derived from the oolite shoal of the Balsthal Formation. This is improbable even though the Knollen Bed can be followed through Canton Aargau and Canton Schaffhausen far into southern Germany (Gygi, 1969a, pl. 19). Another unsolved problem is the low sedimentation rate of the lower Baden Member near Villigen (section RG 62, bed no. 121) and near Mellikon (section RG 70, beds no. 120–124 in Gygi, 1969a, pl. 17).

Isostatic reaction of the lithosphere to loading with sediment or ice, or to unloading for instance by rapid melting of a thick ice sheet, is not instantaneous like that of a cargo-ship floating on water. Water has an incomparably much lower viscosity than the material in the mantle below the lithosphere in the earth interior. Therefore, the highest *rates of sedimentation* as were calculated for strata of Late Jurassic age in northern Switzerland must be compared with a high, measured *rate of isostatic adjustment* of the lithosphere. This is essential when reconstructing synsedimentary tectonics (chapter 9.17). The isostatic uplift of Fennoscandia in northern Europe since the decline of the last glaciation of the Pleistocene is a natural experiment that can be used to calculate how high the rate of isostatic adjustment of the lithospere can be. The ice sheet over Fennoscandia melted away after the end of the last glaciation much faster than the relieved lithosphere below could rise to isostatic equilibrium. Even now, thousands of years after the end of the Pleistocene, the isostatic rebound of the lithosphere below Fennoscandia continues.

Sauramo in Press & Siever (1982, fig. 18–30) found that the *amount* of isostatic uplift in the central part of Fennoscandia, below the Gulf of Bothnia, was as much as 100 m during the past 5000 years. This corresponds to a *rate* of uplift of on average 2 cm per year. This *vertical*, isostatic rate of uplift of the lithosphere compares well with the *lateral* rate of drift that was calculated in global plate tectonics. Sedimentation rates calculated for formations and members of Late Jurassic age in northern Switzerland were seldom greater than 2 m per 10000 years (Gygi, 1999, fig. 1–3). The current rate of isostatic adjustment of the lithosphere under central Fennoscandia is therefore roughly 100 times greater than the major sedimentation rates that were calculated for this study. Consequently, the lithosphere was at no time off isostatic equilibrium during the Late Jurassic in northern Switzerland.

9.15 Palaeobathymetry

Both sedimentology and the geometry of sedimentary bodies provide for some rather detailed marks for palaeobathymetry. Terrestrial environments are documented by palaeosols with rootlets or with calcrete nodules that can have calcite rays below the surface. Thin lignite layers are evidence of freshwater swamps. The land surfaces in the studied sediments must have been very flat and were probably never more than slightly above spring-tide level. This is indicated by a presumably eustatic sea-level rise that occurred in the Hypselum Subchron (Gygi, 1986, fig. 4) and can be estimated to have been only about 5 m in section RG 307 near Péry (fig. 181). This rapid, but small-scale rise was sufficient to flood the then exposed parts of the upper Günsberg Formation and of the coeval Röschenz Member. The marine transgression proceeded from the margin of the Günsberg Formation near Günsberg to beyond Bressaucourt near Porrentruy. It can be read from figure 173 that this corresponds to a palinspastic distance of more than 30 km.

Stromatolites from the intertidal zone with mud cracks (fig. 177) and with fenestrae (birdseye pores: fig. 178) are the most accurate indicators of palaeodepth that could be found. These and coarsely crinkled stromatolites as were figured by Gygi (1992, fig. 12–13) can be interpreted to be documents of the upper intertidal zone (Gygi, 1992:818). There is no evidence that the difference between low-tide and flood-tide level was significant in the epicontinental basin of northern Switzerland. Stromatolites must be studied and interpreted with care, because microbialites like stromatolites and oncoids were found to occur in the investigated sediments from the upper intertidal zone down to the basin floor at a depth greater than 100 m, as for instance in the Mumienmergel Bed (see above).

Calcareous ooids were accreted from the lowermost intertidal zone down to a depth of the order of 5–6 m and were finally deposited in water no deeper than about 10 m. The bathymetric range in which marine iron ooids could be *accreted* is very much greater. An oolitic iron ore was formed in the equivalent of the Liesberg Member at a depth of about 10 m near Chamesol in France just across the Swiss border, 21 km west-southwest of Porrentruy. Gygi (1981) concluded, using different lines of evidence, that the greatest depth where iron ooids can be *accreted* is at about 100 m. Glauconite is known to occur in the Vorbourg Member (see above), where it was probably formed in the shallow subtidal zone. Pure and mature, cauliflower glauconite pellets occur in the thin sediments of succession 1 mainly in Canton Schaffhausen where they were formed in water that was substantially deeper than 100 m. The pellets float in a matrix of carbonate or argillaceous mud.

A bathymetrically controlled boundary between authigenic formation of cauliflower, mature glauconite pellets and accretion of iron ooids was found to exist both in *vertical* and in isochronous, *lateral* facies changes. All of the available evidence indicates that this boundary was at a water depth of about 100 m in Late Jurassic time in northern Switzerland. Cauliflower glauconite pellets were formed in water that was deeper than 100 m. It cannot be decided whether the bathymetric ranges of iron-ooid accretion and formation of cauliflower glauconite pellets touched each other or whether they somewhat overlapped. The vertical change took place near Blumberg in the Lamberti Bed that is, according to Zeiss (1955, fig. 31), only about 5 cm thick. The bed was deposited either during a fraction of a subchron or at most during one entire ammonite subchron. Therefore, if an overlap of the depth ranges of cauliflower glauconite pellet and iron-ooid formation existed, it must have been insignificant. This cannot be checked in the lateral facies change between the iron-oolitic Schellenbrücke Bed and the glauconitic Glaukonitsandmergel Bed, because outcrops are few and too distant.

It is not yet certain whether the boundary between the bathymetric ranges of formation of cauliflower glauconite pellets and of iron ooids *was* in fact at about 100 m in northern Switzerland during the Late Jurassic. The depth of the boundary of about 100 m could be a special case that has as yet to be confirmed elsewhere in sediments of different age, but that were laid down in a similar palaeoclimate. Depth of the boundary probably depends on climate or, more precisely, on mean water temperature at the pertinent depth in the deep subtidal zone. It is to be expected that the boundary would be at a depth of less than 100 m in a cooler climate and in water deeper than 100 m in a fully tropical climate.

It can be concluded from sedimentologic data that the composition of the studied marine macrofauna varied with water depth. Coral bioherms that grew within calcareous oolite, for instance in the Tiergarten Member near Grellingen, Canton Basel-Landschaft, are evidence of a water depth less than 10 m. Growth of the individual coral bioherms that can be laterally crowded at the base of the Günsberg Formation, began in argillaceous mud at a depth that was probably greater than 10 m, because only the upper part of some of these bioherms was observed to be embedded in calcareous oolite near Péry (section RG 458). This is not represented in plate 22 in Gygi (2000a). Much argillaceous mud and some fine-grained detrital quartz in suspension in the water bypassed these bioherms while the bioherms apparently grew vigourously (see also Dupraz, 1999).

The biostrome with predominantly platy hermatypic corals that grew at the surface of argillaceous mud of the Liesberg Member near Liesberg probably began to grow when the surface of the mud bank of the Bärschwil Formation was raised by sedimentation to a depth of less than 30 m. This is estimated, because the base of the Liesberg Member is somewhat more than halfway up in a shallowing-upward succession that began at a depth of probably 70 m (see below) in the uppermost, iron-oolitic Herznach Formation, and ended in very shallow water at the top of the calcareous oolite of the Delémont Member in the middle of the St-Ursanne Formation (fig. 173). It can be concluded from this and from the depth where coral growth began near Péry that hermatypic corals could not live at a depth greater than on average 20 m in all of the investigated environments of Late Jurassic time where hermatypic corals occur.

Specimens of solitary, probably ahermatypic corals are small and rare. One such solitary coral was found in a bioherm of siliceous sponges in the Villigen Formation of section RG 70 near Mellikon (bed no. 17, pl. 17 in Gygi, 1969a, coral to be seen in the right part of the polished slab Gy 1460 that is photographed in pl. 6:23). Another specimen is from bed no. 20 in excavation RG 239 at Summerhalde near Schaffhausen that must have lived at a water depth that is estimated to have been 80 m at least (fig. 187D).

Bivalves prevail in the macrofauna of the marly Banné Member of the Reuchenette Formation that is well-exposed in section RG 341 in the quarry at L'Alombre aux Vaches near Courgenay in Canton Jura. The member was sedimented after a rapid relative sea-level rise above a crinkled, intertidal stromatolite (bed no. 33 of section RG 341, polished slab Gy 4000). The upper surface of bed no. 34 above is bored and covered with a rusty crust (rock sample Gy 4001). The bivalves of the Banné Member must therefore have lived in very shallow water. Ammonites are rare in the member as for instance *Aspidoceras* cf. *acanthicum* (Oppel) J 30714 that was figured by

Gygi (1995, fig. 17/4). Bivalves are most abundant in the macrofauna of the lower Reuchenette Formation in section RG 21 on Mt. Born near Olten (Gygi, 1969a, pl. 18). This macrofauna with mainly bivalves lived at a greater water depth than that of the Banné Member. The lower Reuchenette Formation near Olten was laid down at a water depth that is estimated at about 30 m (fig. 188), because ammonites are fairly abundant in it, but there are no hermatypic corals.

It is the purpose of the following discussion to give evidence that ammonite abundance increases to more than 50% of the macrofauna when the water becomes substantially deeper than 30 m, and that water depth from about 40 m down can be concluded from the varying composition of the ammonite fauna (fig. 188A).

Water depth at the beginning of the Late Jurassic near Blumberg north of Canton Schaffhausen is assumed to have been at least 100 m. This is the depth where accretion of iron ooids turned to glauconite formation during a relative sea-level rise. Water depth was less than 100 m in Canton Aargau and in eastern Canton Solothurn at the beginning of the Late Jurassic (fig. 187A). This is evident from the fact that iron-ooid accretion continued in that region from the Middle Callovian of the Middle Jurassic to the end of the Middle Oxfordian Densiplicatum Subchron in the Late Jurassic. Formation of mature glauconite pellets commenced in Canton Aargau and in eastern Canton Solothurn only when water depth became greater than 100 m at the beginning of the Antecedens Subchron during deposition of the condensed bed at the base of the Birmenstorf Member. The uncondensed, normal facies of the Birmenstorf Member above must then have been sedimented at a depth that was significantly greater than 100 m, provided that the relative sea-level rise continued to the Luciaeformis (*olim* Parandieri) Subchron (fig. 187B). Continuing relative sea-level rise after the eustatic rise in the Antecedens Subchron is indicated by the increase of the percentage of Haplocerataceae from the Mumienkalk Bed upward to the unnamed glauconitic marl at the top of succession 1 in Canton Schaffhausen (table 80).

Water depth increased during deposition of succession 1 both in Canton Aargau and in Canton Schaffhausen. The abundance of Haplocerataceae in the ammonite fauna of the Schellenbrücke Bed is 9% (table 78) and 51% in the younger, normal facies of the Birmenstorf Member above in Canton Aargau (table 80). In Canton Schaffhausen, the percentage of Haplocerataceae grows vertically from 34% in the Glaukonitsandmergel Bed to 49% in the thin, unnamed glauconitic marl of Luciaeformis age (above the Mumienkalk Bed) that is time-equivalent with the normal facies of the Birmenstorf Member in Canton Aargau (table 80). In the iron-oolitic Schellenbrücke Bed of Canton Aargau and in the glauconitic, time-equivalent Glaukonitsandmergel Bed from deeper water in Canton Schaffhausen, the percentages of Haplocerataceae in the ammonite fauna are 9% and 34%, respectively (table 78). Both the lateral transition from iron-oolitic to glauconitic facies and the concomitant increase of the percentages of Haplocerataceae indicate lesser water depth in Canton Aargau and deeper water in Canton Schaffhausen during the Cordatum Subchron. This is evidence that the difference in water depth that existed between the two regions at the beginning of the Late Jurassic (fig. 187A) persisted to the Cordatum Subchron, and that the relative sea-level rise at that time may have been equal in Canton Schaffhausen and in Canton Aargau.

The iron-oolitic facies of the uppermost Herznach Formation at the beginning of the Late Jurassic in northwestern Switzerland documents that the epicontinental basin was then less than 100 m deep. The iron ooids float in a muddy, argillaceous matrix and are therefore concluded to have been accreted *in situ*. Ammonites prevail in the uppermost Herznach Formation of northwestern Switzerland, for instance in section RG 280 near Liesberg (Gygi, 2000a, pl. 30, bed no. 6). This indicates that the water depth at the beginning of the Late Jurassic was in that region at least about 40 m, provided that the following argumentation is correct: The coral limestone of the lower Olten Member grades laterally into the Geissberg Member (fig. 173). There are no hermatypic corals in the Geissberg Member that was therefore sedimented at a depth greater than on average 20 m to conclude from the depth of the base of the Liesberg Member (see above). However, it must be noted that the uppermost part of the Geissberg Member in the area of Bözberg, 7 km west of Brugg, Canton Aargau, is a biocalcarenite (bed no. 4 of section RG 59, Bözbergstrasse, Gygi, 1969a, pl. 5:22). The uppermost Geissberg Member even includes some calcareous ooids in the quarry of Hundruggen 1 km to the south-southwest, northwest of Linn (section RG 58, bed no. 14). Few perisphinctacean ammonites, but numerous bivalves occur in the Geissberg Member. Ammonites of mainly Hypselocyclum age are fairly abundant in the lower Reuchenette Formation of section RG 21 (Gygi, 1969a, pl. 18) near Olten (fig. 188B), but bivalves prevail in that macrofauna. The much greater abundance of ammonites in this macrofauna as compared with that of the Geissberg Member is evidence of a somewhat greater water depth in the lower Reuchenette Formation near Olten that may have been about 30 m. The lower Reuchenette Formation grades east of Olten into the Baden Member (fig. 173), where ammonites prevail in the macrofauna of section RG 28 near Schönenwerd. A water depth of about 40 m can then be estimated for deposition of the lower Baden Member between Schönenwerd and Villigen (fig. 187D).

Succession 1 is shallowing-upward in northwestern Switzerland. Sedimentation of the succession filled the marginal part of the epicontinental basin up to sea level to conclude from an intertidal stromatolite in the lower Vorbourg Member above (fig. 178). The fossil bed that was recorded by Gygi & Persoz (1986, table 2) in the distal part and about in the middle of what was then called Terrain à chailles (now: Sornetan Member) includes a macrofauna with almost exclusively ammonites. The age of the fauna is the Cordatum Subchron. Some of the ammonites in the bed were figured by Gygi & Marchand (1993). Most of the ammonites in the fossil bed in the distal Sornetan Member are cardioceratids (op.cit., fig. 4). The mean abundance of cardioceratids in the ammonite fauna is, according to Gygi & Marchand (1993, fig. 4), about 80%. The coeval, iron-oolitic and almost glauconite-free Schellenbrücke Bed was sedimented at a water depth of less than 100 m. Mature, cauliflower-glauconite pellets are very abundant in the coeval Glaukonitsandmergel Bed in Canton Schaffhausen. This indicates a depth of deposition of the Glaukonitsandmergel Bed of significantly more than 100 m. Cardioceratids are 19% of the ammonites in the Glaukonitsandmergel Bed, and 43% of the ammonites in the Schellenbrücke Bed (table 80). The pronounced predominance of cardioceratids in the

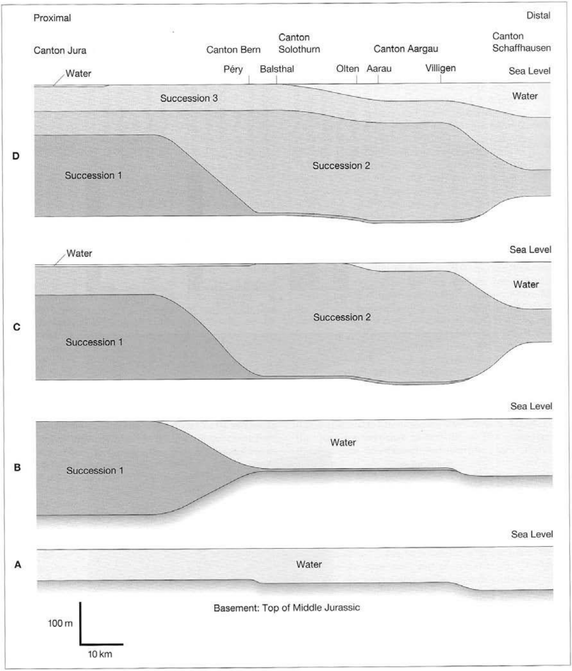


Fig. 187. Original water depth, successive stages of sedimentation and resulting water depth as well as stages of differential basement subsidence in the epicontinental Rhodano-Swabian basin of northern Switzerland during deposition of successions 1–3 in Late Jurassic time.

Thicknesses are decompacted and partially recompacted using the nomogram by Perrier & Quiblier (1974, fig. 11) that was drawn in order to decompact shales. Following Terzaghi (1940), it is assumed that lime mud (carbonate ooze) is compacted about as much as argillaceous mud. Note the great vertical exaggeration of the sections that can be read from the scale. Compare with fig. 173.

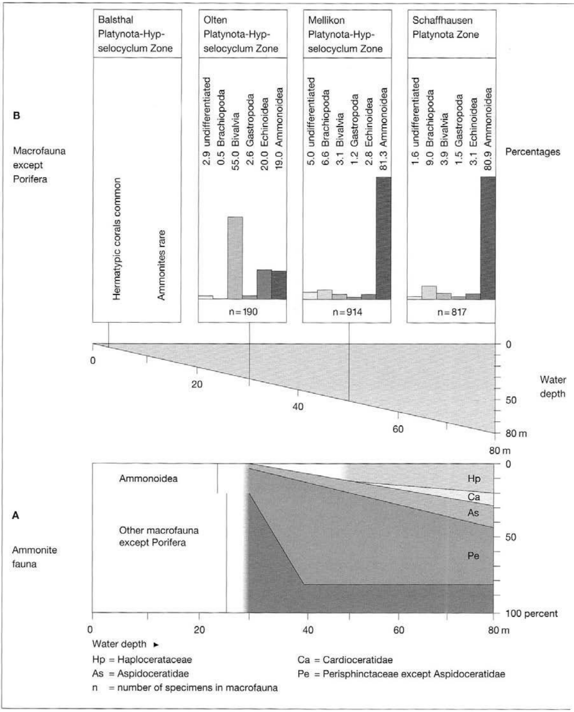


Fig. 188. The interrelation between water depth of the epicontinental, Rhodano-Swabian basin in northern Switzerland in La Jurassic time, and the composition of the fossilized part of the macrofauna.

A: Variation in the abundance and in the composition of the ammonite fauna of Early Kimmeridgian sediments with increasing water depth.

B: Variation in the composition of the whole macrofauna, except Porifera, with increasing water depth. After Gygi (1986, fig. 6), modified.

ammonite fauna of the fossil bed in the distal Sornetan Member is evidence that the bed was laid down at a water depth that was much less than that of the Schellenbrücke Bed.
Bivalves of the genus *Pholadomya* predominate in the macrofauna of the upper Sornetan Member not only in the distal part of the member above the fossil bed. This is the "Pholadomyen" of Etallon (1862). A mass occurrence of *Pholadomya* was found in the lower Crenularis Member of section RG 63 near Villigen, Canton Aargau. *Pholadomya* is abundant among bivalves in the lower Reuchenette Formation of section RG 21 near Olten. Bivalves prevail with 55% in the macrofauna of the Hypselocyclum Chron in this section (fig. 188B), but ammonites are quite common, being 19% of the macrofauna. The absence of hermatypic corals and the relative abundance of ammonites are thought to be indicative of a water depth of about 30 m near Olten at that time. There is no evidence that the water depth was much greater in Hypselocyclum time near Schönenwerd east of Olten. It was noted above that ammonites prevail in the macrofauna of that age in bed no. 47 of section RG 28 near Schönenwerd. Therefore it must be concluded that the change from the bivalve-dominated macrofauna of the lower Reuchenette Formation near Olten to the coeval, ammonite-dominated macrofauna between Schönenwerd and Villigen was caused by a difference in water depth that could have been as slight as 10 m (fig. 188A). 40 m are the most probable water depth at Hypselocyclum time during deposition of the Baden Member near Schönenwerd, Möriken and Villigen.
Provided that the climatic change and mainly the difference in mean annual water temperatures above the seafloor between the Cordatum Subchron and the Hypselocyclum Chron was insignificant, it can be assumed that the upper Sornetan Member with abundant *Pholadomya* was sedimented on average at about the same depth of 30 m like the lower Reuchenette Formation near Olten. The depth of deposition of the fossil bed in the middle of the distal part of the Sornetan Member can be estimated at less than 40 m, provided that the bathymetrically controlled change from predominance of bivalves to an ammonite-dominated macrofauna occurred *vertically* as abruptly in the Sornetan Member as it did *laterally* in the lower Reuchenette Formation between Olten and Schönenwerd (fig. 188A). The fossil bed in the distal Sornetan Member is almost exactly halfway up in the shallowing-upward succession that begins in the uppermost, iron-oolitic Herznach Formation with mostly ammonites in the macrofauna and ends at the top of the Grellingen Member or of the calcareous oolite of the Delémont Member, respectively, in very shallow water (fig. 173). When the rate of sedimentation and of relative sea-level rise during deposition of succession 1 are rated to have been constant, then the water depth at the beginning of the Late Jurassic in northwestern Switzerland must have been more than 60 m and less than 80 m and is therefore assumed to have been about 70 m (fig. 187A).
The bathymetric profile at the end of deposition of succession 1 was the following (fig. 187B): Water depth in northwestern Switzerland was about zero. The seafloor between Günsberg and eastern Canton Aargau was flat at an even depth of about 110 m. This is concluded from the vertical iron-ooid-glauconite transition at the base of the Birmenstorf Member that occurred at the same time, at the end of the Densiplicatum Subchron, in all of the sections that were investigated in this region. Further east, the water depth increased to an estimated 130 m at the end of deposition of succession 1 in Canton Schaffhausen.
The depositional profile in the lowermost Reuchenette Formation and in the time equivalents above succession 3 between Balsthal and Schaffhausen in Platynota or Hypselocyclum time of the Early Kimmeridgian cannot be calibrated bathymetrically as well as the profile at the end of deposition of succession 1. Biostromes and small bioherms of hermatypic corals embedded in calcareous oolite of presumed Hypselocyclum age above a palaeosol (fig. 175) in several sections near Balsthal indicate a very shallow water depth that was less than 10 m at that time (Gygi, 2000a, pl. 44, and fig. 188B in this study). The macrofauna of mainly Hypselocyclum age in the lower Reuchenette Formation of section RG 21 near Olten (Gygi, 1969a, pl. 18) includes mostly bivalves (fig. 188B), but ammonites are with 19% relatively abundant in the macrofauna. Perisphinctaceae including some Aspidoceratidae are the only ammonites represented. The macrofauna lived at a depth that is estimated at about 30 m, because ammonites are much more abundant in this Kimmeridgian fauna than in the macrofauna of the Oxfordian Geissberg Member further east. Ammonites prevail in the macrofauna of the lower Baden Member between Schönenwerd and Villigen (see above). They probably lived at a depth of about 40 m. 81% of the macrofauna of mainly Hypselocyclum age in section RG 70, bed no. 124, near Mellikon are ammonites (Gygi, 1969a, pl. 17 and fig. 188B in this paper). Haplocerataceae are more abundant at Mellikon than they are on average in the lower Baden Member further west. They indicate that the water must have been deeper than 40 m near Mellikon at that time. The abundance of Haplocerataceae in the ammonite fauna of Platynota age that was excavated from section RG 239 near Schaffhausen (fig. 160) is greater than near Mellikon. The water depth at this time near Schaffhausen was therefore greater than near Mellikon.
Water depth in Platynota and in Hypselocyclum time of the Early Kimmeridgian near Mellikon and near Schaffhausen can only be estimated according to the lateral change in the composition of the macrofauna as is represented in figure 188A. The lateral change in the composition of the Kimmeridgian macrofauna between Balsthal and Schaffhausen above succession 3 can be compared with the lateral faunal change in the uppermost part of succession 1. The lateral change of the macrofauna in the uppermost succession 1 is not documented in as much detail as it is in the Early Kimmeridgian, because macrofossils are uncommon in the Pichoux Formation except at its base. But the depth of deposition of the upper St-Ursanne Formation and of the upper Birmenstorf Member can be estimated fairly well. The vertical transition from iron-ooid accretion to glauconite formation occurred in the condensed bed at the base of the Birmenstorf Member at a depth of at least 100 m. The normal facies of the Birmenstorf Member above can therefore be concluded to have been sedimented at a depth of about 110 m. Perisphinctaceae including Aspidoceratidae are 47% and Haplocerataceae are 51% of the ammonite fauna in the normal facies of the Birmenstorf Member in Canton Aargau (table 80). The depth of deposition of the upper St-Ursanne Formation was less than 10 m, about 100 m less than that of the normal facies of the Birmenstorf Member.

Varying water depth in the deep subtidal zone, where most sediments are mud-grade and give no information of water depth, can therefore be concluded from the lateral variation in the composition of the Early Kimmeridgian ammonite fauna (fig. 188A). From a depth of about 40 m down, where the *abundance* of ammonites in the macrofauna does not increase any more, the *composition* of the ammonite fauna gives information of further increasing depth. An example of this is the lateral transition from the Buix Member of the upper St-Ursanne Formation to the upper Birmenstorf Member in Canton Aargau. The lagoon of the Buix Member was probably less than 10 m deep and was rimmed by the shoal of calcareous oolite sand of the Tiergarten Member. Ammonites are rare in the sediment of the lagoon floor of the Buix Member. Only perisphinctaceans were found in the Buix Member that were figured by Gygi (1995). Perisphinctaceae are then 100% of the few ammonites that were fossilized at this shallow depth. The depth of deposition of the upper Birmenstorf Member was concluded above to have been about 110 m. Perisphinctaceae including Aspidoceratidae are only 47% of the ammonite fauna in this member. Haploceratacea were never found in the lagoonal Buix Member, but they are 51% of the ammonites that occur in the normal facies of the Birmenstorf Member in Canton Aargau (table 80).

Increase of water depth in a lateral, isochronous facies transition is then indicated in the ammonite fauna by a *diminishing percentage of Perisphinctaceae*. Aspidoceratidae are always subordinate in this superfamily, but their abundance grows with increasing water depth (fig. 188A). As well, Haploceratacea become more abundant in the ammonite fauna when water becomes deeper. This is documented by the lateral transition from the iron-oolitic Schellenbrücke Bed of Canton Aargau that was laid down in water less than 100 m deep to the coeval, glauconitic Glaukonitsandmergel Bed in Canton Schaffhausen that is evidence of a depth of deposition that was well over 100 m. Haploceratacea are 9% of the ammonite fauna in the Schellenbrücke Bed, and 34% of the ammonites in the Glaukonitsandmergel Bed (table 80). It can also be read from table 80 that the percentage of Haploceratacea increases vertically from the Glaukonitsandmergel Bed to the thin, unnamed glauconitic marl above the Mumienkalk Bed in Canton Schaffhausen. This is additional evidence of the occurrence of a substantial relative sea-level rise during deposition of succession 1 both in Canton Schaffhausen and in Canton Aargau. The difference in water depth between the two regions and the relative sea-level rise were responsible for the time difference between the onset of glauconite formation near Blumberg at the beginning of the Late Jurassic and later, at the beginning of the Antecedens Subchron, in Canton Aargau when the water there also became deeper than 100 m, too deep for the accretion of iron ooids, and deep enough for formation of fully evolved glauconite pellets floating in muddy sediment.

However, there is no simple relation between water depth and the percentages of Perisphinctaceae and especially of Haploceratacea in an ammonite fauna. This becomes evident when the pertinent percentages in table 80 are compared between the upper Birmenstorf Member in Canton Aargau and the coeval, unnamed glauconitic marl above the Mumienkalk Bed in Canton Schaffhausen. It is probable that the difference in water depth between these beds remained to be about the same as it was at the beginning of the Late Jurassic (fig. 187A), or as it was between the Schellenbrücke Bed and the coeval Glaukonitsandmergel Bed. Nevertheless, Haploceratacea are 51% and Perisphinctaceae, including Aspidoceratidae, 47% of the ammonites in the upper Birmenstorf Member in Canton Aargau that was sedimented at a depth of about 110 m. The depth of deposition of the coeval glauconitic marl in Canton Schaffhausen must have been greater (fig. 187B), but Haploceratacea are only 49% and Perisphinctaceae are 50% of the ammonite fauna in this bed (table 80).

An increasing depth of deposition can be inferred beginning with the slightest water depth in the lower Schwarzbach Formation (SWB, Early Kimmeridgian) in Canton Schaffhausen, to the upper Birmenstorf Member (BIR, Middle Oxfordian) in Canton Aargau, and to the Glaukonitsandmergel Bed (GSM, Early Oxfordian) in Canton Schaffhausen that was deposited at the greatest depth. The percentages in the ammonite fauna of the three lithostratigraphic units of different age are

SWB:	Perisphinctaceae 65%, Haploceratacea 24%:	slightest water depth
BIR:	Perisphinctaceae 47%, Haploceratacea 51%:	intermediate water depth
GSM:	Perisphinctaceae 44%, Haploceratacea 34%:	greatest water depth

According to Perisphinctaceae, the lower Schwarzbach Formation was deposited at the slightest depth, and the Glaukonitsandmergel Bed at the greatest depth of the three units. The palaeodepth of the lower Baden Member near Mellikon must have been, to judge from the relative percentages of Perisphinctaceae and Haploceratacea as indicated in figure 188A, somewhat greater than that estimated for this member further west (see above). The significant decrease of the percentage of Perisphinctaceae (without Aspidoceratidae) and the increasing percentage of Haploceratacea between Mellikon and Schaffhausen that can be read from figure 188A is evidence that the lower Schwarzbach Formation near Schaffhausen was sedimented at a considerably greater depth than the lower Baden Member near Mellikon. A water depth of about 50 m is inferred for Platynota time near Mellikon. The water depth at this time near Schaffhausen, according to the relatively high percentage of Perisphinctaceae, was probably less than 100 m when the lower Schwarzbach Formation was laid down. But the rich assemblage of very well-preserved siliceous sponges mentioned above that was found at locality RG 216 in the middle Schwarzbach Formation on Siblinger Randen near Siblingen, less than 10 km west of Schaffhausen is reason to believe that the depth in Platynota time near Schaffhausen was not much less than 100 m. The sponge assemblage near Siblingen resembles that of the Birmenstorf Member, the depth of deposition of which is relatively well known and greater than 100 m. The two small sponge bioherms that were seen in 1980 in the lowermost Pichoux Formation of section RG 307 near Péry (bed no. 22, Gygi 2000a:34 and pl. 22) grew also at a depth greater than 100 m. This is indicated by fully evolved glauconite pellets in the bed (fig. 187B).

Samples of lime mudstone like that of the peritidal Vorbourg Member, of the Letzi Member from intermediate depth or of the Wangental Member from greater depth are all very similar. They give no information of depth of deposition unless the composition of the macrofauna in the corresponding lithostratigraphic unit is known. The same is the case in fresh samples or drill cores of argillaceous mudstones as they occur in the Bure Member from very shallow water, in the Renggeri Member from intermediate depth, or in the lowermost, distal Effingen Member that was laid down at a depth greater than 100 m.

9.16 Geometry and internal structure of sedimentary bodies

It is represented in figure 187A that the epicontinental, Rhodano-Swabian basin was at the beginning of the Late Jurassic about 70 m deep in northwestern Switzerland, and somewhat deeper in eastern Canton Solothurn. The lithology of the uppermost Herznach Formation, a thin bed of Early Oxfordian age in northwestern Switzerland, is invariably iron ooids floating in a matrix of argillaceous mud, and ammonites prevail in the macrofauna of the bed. The uniform facies of the thin and widespread bed indicates similar depth of deposition and therefore a fairly flat submarine topography. The topography of the seafloor in the Early Transversarium Chron must have been almost perfectly flat between Günsberg in Canton Solothurn and Gansingen in eastern Canton Aargau (fig. 187B). The vertical transition from iron-ooid accretion to glauconite formation that was caused by a relative sea-level rise occurred at the same time everywhere in this area. Evidence of this are the ammonites that were found in the condensed bed at the base of the Birmenstorf Member (see above). The "swell" in the condensed sediments of the Early Oxfordian below, that was presumed by Norris & Hallam (1995) to exist in eastern Canton Aargau and that was accepted by Allenbach (2002, fig. 15), is inconsistent with this.
The top of the St-Ursanne Formation must have been sedimented just below sea-level to conclude from the widespread peritidal facies of the Vorbourg Member above. The mineral stratigraphic correlation C by Gygi & Persoz (1986, pl. 1A) is evidence that the upper boundary of the St-Ursanne Formation is isochronous between Bressaucourt and the distal margin of the carbonate platform. Consequently, the top of the formation was flat, and the formation was indeed a carbonate *platform*. The internal structure of the Bärschwil Formation under the platform of the St-Ursanne Formation is probably planar, provided that the facies boundaries at the base and at the top of the Sornetan Member are flat. However, the measurements of thickness of the members within the Bärschwil Formation and the ammonites collected from *in situ* in the formation are not numerous enough to confirm this.
The distal part of the upper St-Ursanne Formation, the Tiergarten Member with coral bioherms within calcareous oolite, grades laterally into the calcareous mud of the Pichoux Formation. The Pichoux Formation has the configuration of a wedge (fig. 173). The Pichoux Formation grades at its distal margin into the Birmenstorf Member that is only about 5 m thick. Siliceous sponges and ammonites are the main elements of the macrofauna in the vertically alternating carbonate and argillaceous mud matrix of this member. The vertical change from iron-oolitic to glauconitic facies occurred in the condensed bed at the base of the Birmenstorf Member at a depth of about 100 m. Ammonites prevail in the macrofauna of the Birmenstorf Member. The Pichoux Formation was then sedimented on a depositional slope and is a carbonate *ramp*, albeit with a minimal inclination. The *lateral*, isochronous facies transition within the upper Pichoux Formation between the ammonite facies of the Birmenstorf Member in deeper water and the coral facies from shallow water in the Tiergarten Member is similar to the *vertical* facies succession that was described above to have occurred in succession 1 in northwestern Switzerland. Sedimentation of the proximal, thick succession 1 began in northwestern Switzerland with the iron-oolitic ammonite facies at the base of the Bärschwil Formation, continued with mainly bivalves in the upper half of the Sornetan Member, and ended with the coral reef facies in the upper St-Ursanne Formation. Consequently, succession 1 is shallowing-upward in northwestern Switzerland. It is a submarine, argillaceous mud bank that is capped by a carbonate platform. The distal margin of the flat top of the argillaceous mud bank of the Bärschwil Formation and of the distal margin of the carbonate platform of the St-Ursanne Formation are almost exactly above each other, and so are, approximately, the distal margins of the Bärschwil and of the Pichoux Formation (fig. 173). The reason for this nearly perfect congruence cannot be given. There was no progradation. It is doubtful whether a net eustatic sea-level rise alone that occurred during deposition of succession 1 was sufficient to explain this.
Succession 1 in northwestern Switzerland has an averaged, compacted thickness of 185 m. The primary, uncompacted thickness of these sediments is difficult to assess, because the thickness mainly of Mesozoic deposits that were laid down after the Middle Kimmeridgian and of those sedimented during the Tertiary cannot even be estimated in this region. If an overburden of 400 m is envisaged, then the primary thickness of the proximal succession 1 would have been, as read from the nomogram of figure 11 by Perrier & Quiblier (1974), 215 m (fig. 187B). This thickness was accommodated in a basin with an initial water depth that is rated at 70 m. The two eustatic sea-level rises during the Cordatum and the Antecedens Subchron and the basement subsidence induced by the additional water load probably amounted to a total of about 20 m (Gygi, 1981). The resulting accommodation space of 90 m must then have been augmented by whatever process of basement subsidence by 125 m during deposition of succession 1 in northwestern Switzerland (fig. 187B).
Sedimentation of succession 1 began in northwestern Switzerland as well as in eastern Canton Solothurn at a similar water depth that must have been considerable. It is certain that the great difference in thickness within succession 1 of on average 185 m of compacted sediment in northwestern Switzerland and only 5 m of compacted sediment in eastern Canton Solothurn led to a regional difference in basement subsidence under the very different sediment load. The greater subsidence under the load of the thick, proximal part of succession 1 was probably mostly the effect of isostatic adjustment of the lithosphere and of compaction of sediments older than the Late Jurassic. It must have been principally the exogenic process of *sedimentation* with an extreme regional variation in rates of sedimentation that was the cause of greater basement subsidence under the proximal part of succession 1.
The trough-like depression of the base of succession 1 under the proximal, thick part of succession 1 is therefore caused by the much greater load of the succession in northwestern Switzerland as compared with eastern Canton Solothurn. The

trough evolved from the beginning of the Late Jurassic to the end of the Transversarium Chron. If formation of the trough was mainly the effect of a process in the earth interior (endogenically controlled), it would be difficult to explain why the distal margin of the trough is exactly beneath the depositional slope of the top of succession 1 where it is thinning out in the distal direction (fig. 187B). It can be ruled out that the trough existed already before sedimentation of succession 1 began as was presumed by Allenbach (2001).
The marginal part of the Rhodano-Swabian, epicontinental basin was filled almost to sea level at the end of deposition of succession 2 between northwestern Switzerland and the region of Balsthal (fig. 187C). Then followed local exposure of the top of the Hauptmumienbank Member that is documented in figure 183. Exposure at some localities of the top of the Steinebach Member is documented by the rock sample with calcite rays Gy 238 from bed no. 3 of the unpublished section RG 15 near Aedermannsdorf, and by figure 176 of a palaeosol near Waldenburg. The combined and averaged, compacted thicknesses of successions 1 and 2 in northwestern Switzerland are 235 m, and 230 m near Balsthal. Sedimentation of succession 2 began near Balsthal at a depth of at least 100 m and ended near sea level. It is therefore shallowing-upward like succession 1 in northwestern Switzerland. The sum of basement subsidence by whatever process under successions 1 and 2 between northwestern Switzerland and Balsthal must then have been almost equal. Part of the subsidence that created the accommodation space for succession 2 in northwestern Switzerland was evidently endogenic. It follows from the similar initial depth of the basin, from the almost equal combined thicknesses of successions 1 and 2, and from partial exposure of the top of succession 2 between northwestern Switzerland and Balsthal, that the average *endogenic* subsidence was equable in the region from the beginning of the Late Jurassic to the end of deposition of succession 2. Such a detailed result cannot be arrived at with the method of backstripping.
Water depth increased during deposition of succession 1 between Günsberg in Canton Solothurn and Canton Schaffhausen independently of sedimentation as is represented in figures 187A and 187B. The difference in water depth between Canton Aargau and Canton Schaffhausen that certainly existed at the beginning of the Late Jurassic, probably remained unchanged during five ammonite subchrons to the end of the Cordatum Subchron at least. A considerable part of the relative sea-level rise that occurred during depositon of succession 1 was caused by a eustatic sea leavel rise during the Cordatum Subchron and another during the late Antecedens Subchron. Endogenic subsidence during sedimentation of succession 1 between Günsberg and Canton Schaffhausen must then have been of minor order and on average about equable. *Endogenic* subsidence was of minor order and on average equable during sedimentation of succession 2 between northwestern Switzerland and Balsthal. If this is so, then the difference in basement subsidence that evolved between Balsthal and northwestern Switzerland during deposition of succession 1 (fig. 187B) was mostly, if not exclusively, controlled by *exogenic* processes. The greater part of basement subsidence first under the thick, proximal part of succession 1 in northwestern Switzerland (fig. 187B) and then under the thick succession 2 near Balsthal (fig. 187C) was the *effect* of loading with sediments. It follows from this that in a shallow epicontinental sea like in the Rhodano-Swabian basin in northern Switzerland during the Late Jurassic, sedimentation itself is, by the weight of the deposits, the cause for the creation of a major part of the total accommodation space. This can be concluded from the geometry and from the varying depth of deposition of the sediments.
The internal structure of succession 2 is much more complicated than that of succession 1. It is progradational in the proximal part (fig. 173), albeit with a low inclination of the prograding sigmoids. However, the declivity of the sigmoids was sufficient that slumps and turbidites could occur. Evidence of this is that the whole Effingen Member is of Bifurcatus age near Péry and near Günsberg. This is documented by ammonite number 18 in figure 173, the *Perisphinctes (Dichotomoceras) bifurcatus* (Quenstedt) FSL 221 055 that was found by R. Enay in the lower Günsberg Formation in section RG 14 in the Gschlief landslide above Günsberg (Gygi, 1969a, pl. 18). The ammonite was figured by Gygi (1995, fig. 17/2). The younger and thicker part of the Effingen Member above the Gerstenhübel Beds near Auenstein in Canton Aargau was sedimented during the subsequent Hypselum Subchron. This can be concluded from the mineral stratigraphic correlations E at the base of the Gerstenhübel Beds and correlation F at the top of this unit (Gygi & Persoz, 1986, pl. 1A). Enay & Gygi (2001) had reason to assume that the age of the Gerstenhübel Beds is the Grossouvrei Subchron of the Late Bifurcatus Chron. The age of the upper Effingen Member in Canton Aargau is documented by ammonite no. 21 in figure 173. This is the *Euaspidoceras hypselum* (Oppel) J 27259 that was figured by Gygi (2000a, pl. 10:1). The progradational internal structure of the proximal part of succession 2 is also evident from the Günsberg Formation that advanced in the distal direction over the proximal Effingen Member. Progradation of the Günsberg Formation ended in the Late Bifurcatus Chron and reversed to backstepping during transgression of marine facies over peritidal and even supratidal sediments in Hypselum time far in the proximal direction. This transgression was followed by regression when the Steinebach Member prograded at the end of deposition of succession 2.

9.17 Synsedimentary tectonics

Synsedimentary tectonics during the Late Jurassic in the investigated region should in the first place be distinguished from tectonics that occurred much later, during the orogeny of the Jura Mountains in the Tertiary. Synsedimentary tectonics were envisaged by Gygi (1969a) as a possible cause of unusually great sediment thicknesses that he found to occur locally. Small-scale thrusting during the folding of the Jura Mountains can now be seen to have caused the apparently great thickness of more than 100 m of the Verena Member in the quarry at Gänsbrunnen, Canton Solothurn (sections RG 430 and 431 in Gygi, 2000a, pl. 40). Buxtorf (1907:58) concluded that what he called "Kimmeridgien" in the railway tunnel below the quarry was 130 m thick. Gygi (2000a, pl. 40) measured the thickness of the Reuchenette Formation in the southernmost part of the quarry at Gänsbrunnen to be only 12 m. The "Kimmeridgien" of Buxtorf in the tunnel is therefore mostly the Verena Member that can now be observed in the quarry above to be tectonically repeated by three small thrusts. Gygi

(1969a) measured the nearby section RG 7 in the upper part of Wolfschlucht gorge west of Herbetswil. The great thickness anomaly in the Steinebach Member mentioned on page 110 of that study and represented in figure 9 by Gygi (1969a) is probably the result of tectonic thrusting in the Tertiary that could not be recognized when the section was measured in 1963 because of partially poor outcrop quality. Insufficient outcrop conditions turned out to be the reason that small-scale thrusting was overlooked in 1963 when section RG 15 was measured in the uppermost part of Horngraben gorge near Aedermannsdorf, Canton Solothurn (Gygi, 1969a:112 and fig. 11). This was only recognized in 1986 when the tectonically undisturbed section RG 440 east of Mt. Rüttelhorn (Gygi, 2000a, pl. 43) was measured. Complicate tectonics in the Tertiary led to the partial repetition of section RG 406 in a ravine southwest of Vermes, Canton Jura (Gygi, 2000a, pl. 37). This was already recorded by Pfirter (1982).

The faults depicted in Gygi & Persoz (1986, fig. 2 and 8), one of which is reproduced here as figure 182, were obviously active during sedimentation. The vertical displacement visible in figure 182 was 2–3 decimeters in the lower part of the figure, and movement along the fault can be seen to have been gradual, and to have ceased in the course of sedimentation. The displacement occurred along a clear-cut plane, although the sediment was unconsolidated when the fault was active. It is possible that this is a small, shallow-rooted, exogenically driven growth fault (see Weimer & Davis, 1977). The thicknesses of the limestone formations and members that were measured and represented in several plates by Gygi (2000a) vary from section to section. Synsedimentary faulting must be assumed to be the cause. Gygi (1986, fig. 3D) thought that the thickness differences that he found to exist in the Balsthal Formation above the thick, argillaceous Effingen Member might be the effect of major growth faults. The thickness of the St-Ursanne Formation in section RG 306 near Liesberg is about 95 m (Gygi, 2000a, pl. 31). Only 4 km to the north-northwest, in the unpublished section RG 397 near Kleinlützel, the same formation is only 35 m thick, 60 m less than near Liesberg. A growth fault is improbable to be the cause. The average thickness of the argillaceous Bärschwil Formation below is only about 120 m. Growth faults can be ruled out as a possible cause of thickness variations in the Balsthal Formation and in the Courgenay Formation above the Röschenz Member that is on average only 35 m thick. Part of this thickness is calcareous, oolitic grainstone that could not be compacted by subsequent sedimentation in Oxfordian time, as for instance in section RG 402 near Röschenz that is represented in plate 33 by Gygi (2000a). The synsedimentary fault in the St-Ursanne Formation between sections RG 306 near Liesberg and RG 397 near Kleinlützel must therefore have been driven by an endogenic process. The total vertical displacement of 60 m, a small part of which was the result of isostasy and of compaction of older sediments under the load of fresh sediment, evolved in a time of less than 500 000 years (see fig. 40 in Gygi, 2000a and fig. 175 here). This important thickness anomaly was mentioned by Gygi (1986:487) and is represented in figure 5 by Gygi (1990c).

The thickness anomaly in the Effingen Member near Riniken northwest of Brugg in Canton Aargau (Gygi, 1990c, fig. 6) is of the order of 60 m like that in the St-Ursanne Formation between Kleinlützel and Liesberg. This can be concluded from the thickness of the Effingen Member that was measured in the well drilled by Nagra near Riniken (Nagra, 1990), and from the elevation where the flat-lying Crenularis Member crops out below the ruin of the castle on Iberg hill only 250 m west of the Nagra borehole. The local, endogenic subsidence of the basement that was about 60 m greater near Riniken than that of the surrounding regions, must have occurred during a time of a few 100 000 years.

Sedimentation in an epicontinental basin is primarily controlled by the initial water depth that provides for the accommodation space that can be filled with marine sediments (fig. 187A). Exogenic subsidence of the basement by loading is the consequence of a net eustatic sea level rise that occurs over a long period of time, but it is mainly caused by the sediment supply to the basin. The combined weight of additional water and of fresh sediment leads to compaction of older sediments below and to isostatic subsidence of the lithosphere (fig. 187B). Most of the increment of water depth during deposition of succession 1 in the starved basin is probably the result of a net eustatic sea-level rise.

100 m was concluded to be the initial water depth of the Rhodano-Swabian, epicontinental basin at the beginning of the Late Jurassic near Blumberg north of Schaffhausen. The depth in northwestern Switzerland at this time was about 70 m (fig. 187A). Deposition of succession 1 ended at about sea level in that region. The initial accommodation space of about 70 m for succession 1 in northwestern Switzerland was augmented to 90 m by eustatic sea-level rises. The decompacted, primary thickness of succession 1 that was accommodated in the resulting space was estimated after Perrier & Quiblier (1974) to have been about 215 m. Basement subsidence of 125 m was necessary to create this accommodation space. The major part of the subsidence was probably isostatic, and a substantial part of the total subsidence was the result of compaction of sediments of Middle Jurassic age below. There is no evidence that endogenic subsidence was on average significant in the whole region at that time.

Sedimentation of succession 2 began in northwestern Switzerland at about sea level and ended at the very shallow depth of a few meters in the lagoon of the Hauptmumienbank Member. The measured and averaged thickness of the succession is in that region 50 m, and the primary thickness was estimated, according to Perrier & Quiblier (1974, fig. 11), to have been about 65 m. Some of this accommodation space was created by a minor eustatic sea-level rise, but this rise occurred late during deposition of succession 2. Consequently, some endogenic subsidence independent of sedimentation was necessary to initiate and to keep going the predominantly shallow-marine sedimentation of the succession. Isostatic subsidence and compaction of succession 1 below as well as of older sediments must have been important in creating the accommodation space for succession 2 in northwestern Switzerland.

Sedimentation of successions 1 and 2 began between northwestern Switzerland and Balsthal in Canton Solothurn in water that was less than 100 m deep. Initial depth in that part of the epicontinental basin did not vary significantly. The combined thickness of the two successions is almost exactly the same in this region. The sediments of the two successions filled the basin up to or very close to sea level. The combined, total thickness of the marine sediments of the two successions is much greater than the initial depth of that part of the basin.

A major amount of basement subsidence caused by whatever process must therefore have occurred, and the sum of subsidence became equal in the whole region at the end of deposition of succession 2.

Succession 1 filled the basin up to sea level in northwestern Switzerland. The decompacted thickness amounted there to about 215 m. Only about 5 m of sediment were laid down at the same time in the adjacent, starved basin of the region of Balsthal. Water depth increased near Balsthal during deposition of the thin succession 1 from an estimated 80 m at the beginning of the Late Jurassic to more than 100 m at the end of the Transversarium Chron. Part or maybe the greater part of this increment was the result of two major eustatic sea-level rises. Endogenic basement subsidence near Balsthal must consequently have been subordinate during sedimentation of succession 1. Endogenic subsidence of the basement was also of minor order when succession 2 with a decompacted thickness of only 65 m was laid down in northwestern Switzerland. This is an indication that *endogenic* basement subsidence was on average slight in both regions during deposition of succession 1 and 2. Conversely, the greater part of the very substantial basement subsidence first under the thick part of succession 1 in northwestern Switzerland, and subsequently under the thick part of succession 2 near Balsthal, was the result mainly of the *exogenic* process of sedimentation.

It is obvious from palaeobathymetry, the extreme, lateral variation in sedimentation rates and from the geometry of the shallowing-upward succession 1 in northwestern Switzerland as well as from the following, likewise shallowing-upward succession 2 near Balsthal, that the weight of sediments was an important factor that caused strong basement subsidence first in northwestern Switzerland under the proximal part of succession 1 (fig. 187B), and subsequently in the adjacent, initially starved basin further east under the thick, basinal part of succession 2 (fig. 187C). The greater thickness of succession 2 near Balsthal as compared with succession 1 in northwestern Switzerland is mostly the consequence of the greater initial accommodation space for succession 2 near Balsthal.

It is now certain that by the sedimentation first of the thick, shallowing-upward succession 1 in northwestern Switzerland, and by the following deposition of the thick, equally shallowing-upward part of succession 2 into the adjacent starved basin, that the lower part of the argillaceous Wildegg Formation was finally brought to the same level as the argillaceous Bärschwil Formation (fig. 173). This is probably the reason why Merian (1821) arrived, with due reservation, at the opinion that the two formations were coeval. Merian was aware that time correlations must be made with fossils rather than by comparing lithology as it was previously done. But he stated that palaeontologic knowledge at his time was as yet insufficient to solve the problem. Numerous ammonites were since collected from the Bärschwil as well as from the Wildegg Formation, many of them from *in situ*. The ammonites prove that the two formations are consecutive in age (Gygi, 1995). In figure 173, the Bärschwil Formation appears to be separated laterally from the Wildegg Formation by the diagonal Pichoux Formation that is of intermediate age and that was sedimented on a depositional slope. The ammonites as figured by Gygi (1995; 2001) document that the St-Ursanne Formation, the Pichoux Formation and the bulk of the Birmenstorf Member in the basin are coeval.

The slight, primary declivity of the carbonate ramp of the Pichoux Formation (fig. 187B) was secondarily enhanced by basement subsidence under the load of the part of succession 2 that was sedimented into the most proximal part of the starved basin (fig. 187C). The diagonal position of the Pichoux Formation that is conspicuous in figure 173, is in a relatively narrow belt in which the distal Bärschwil Formation below, the Pichoux Formation in the middle and the proximal part of the Wildegg Formation above are superimposed in primary, stratigraphic order. This is the case in section RG 30 near Péry (Gygi, 2000a, pl. 22). A natural outcrop where the uppermost part of the Bärschwil Formation, the whole Pichoux Formation and part of the lower Wildegg Formation are well-exposed in vertical, stratigraphic order is on the eastern slope of Court gorge near Moutier that can be overlooked from the western rim of the gorge (Gygi, 2000a, fig. 34). The thicknesses of the Bärschwil and of the Wildegg Formation are about equal at that locality.

Sedimentation of succession 2 began near Günsberg in eastern Canton Solothurn, like in Canton Aargau, at a depth of more than 100 m (fig. 187B). Sedimentation of the succession ended in Canton Solothurn (section RG 15) and in Canton Basel Landschaft (section RG 4, fig. 176) at the top of the oolitic Steinebach Member near sea level (fig. 187C). Succession 2 evidently shallowing-upward in Canton Solothurn. The average, compacted thickness of the Effingen Member in eastern Canton Solothurn is about 210 m and about 200 m in adjacent Canton Aargau. Deposition of the Effingen Member ended near Balsthal at a depth of 10 m at most to judge from the calcareous oolite of the Steinebach Member that was sedimented above. In Canton Aargau, sedimentation of the Effingen Member must have ended at a depth of at least 20 m, because there are no hermatypic corals, but abundant bivalves in the lime mudstone of the Geissberg Member above. This is evidence that succession 2 is shallowing-upward in Canton Aargau as well as in Canton Solothurn. The sum of basement subsidence began to vary between the two regions before the end of deposition of the Effingen Member (fig. 187C).

An abrupt change from argillaceous to carbonate mud sedimentation occurred at the end of deposition of the Effingen Member. Sedimentation of the oolitic Steinebach Member with an average thickness of 15 m began in Canton Solothurn at a depth of no more than 10 m and ended at about sea level. Sedimentation of the carbonate mud of the Geissberg Member with a primary thickness of at least 20 m began in Canton Aargau at a depth of more than 20 m and ended at a depth greater than 20 m (fig. 187C). Bivalves prevail in the Geissberg Member, and hermatypic corals are absent in the macrofauna. The top of the Effingen Member therefore subsided by about 5 m during sedimentation of the Steinebach Member in Canton Solothurn, and by at least 20 m when the Geissberg Member was laid down in Canton Aargau. The mean, compacted thickness of the Geissberg Member is about 15 m like that of the Steinebach Member. The load of the two members that were sedimented on top of the Effingen Member was probably not much different between the two regions. But the top of the Effingen Member subsided about 15 m more when the Geissberg Member was laid down in Canton Aargau. The regional difference of subsidence of 15 m between the base of the Steinebach Member and the base of the Geissberg Member must then be concluded to have been caused by an *endoge* process. The difference in endogenic subsidence between Canton Solothurn and Canton Aargau evolved late during deposition of succession 2.

Sedimentation of the oolitic succession 3 near Balsthal began at about sea level, and it ended there near sea level (fig. 187C–D). The mean thickness of the oolitic succession 3 from Balsthal to the west is about 60 m. Total basement subsidence during deposition of the carbonate platform was then on average of the order of 60 m. Sedimentation of succession 3 began in Canton Aargau at a slow rate with deposition of the thin, slightly glauconitic Crenularis Member. Bivalves prevail in the macrofauna of the member, and there are no hermatypic corals. The initial depth of deposition was then greater than 20 m. Sedimentation of lime mud of the Wangen and Letzi Member above with an uncompacted total, primary thickness of about 50 m, as read from figure 11 in Perrier & Quiblier (1974), occurred at a normal rate. The sedimentation rate dropped sharply for a short time when the thin Knollen Bed was laid down as a regional marker bed between the members. The initial depth of deposition of succession 3 in Canton Aargau was at least 20 m. Uncompacted lime mud with a thickness of 50 m (see above) was accommodated in this part of the basin. Sedimentation of succession 3 ended at a water depth of about 40 m, because ammonites prevail in the macrofauna of the lower Baden Member directly above the top of succession 3. The base of succession 3 therefore subsided from roughly 20 m at the beginning of sedimentation by 70 m to 90 m below sea level at the end of deposition of the succession. This is 30 m more than that the base of succession 3 subsided near Balsthal. In spite of a mostly normal sedimentation rate, succession 3 is deepening-upward in Canton Aargau (fig. 187C–D). The shallowing-upward tendency during sedimentation of the Effingen Member in Canton Aargau must have been halted by increasing endogenic subsidence when the Geissberg Member was laid down. The growing rate of basement subsidence stabilized water depth during deposition of the Geissberg Member. Accelerated endogenic subsidence on a regional scale must have been the cause of the change to a deepening-upward tendency during sedimentation of succession 3 in Canton Aargau.

The distal margin of the thin carbonate platform of the Steinebach Member was to the west of Wangen near Olten (fig. 173). The platform margin stepped back to east of Balsthal during deposition of succession 3 (fig. 187D), probably because enhanced endogenic subsidence that began in Canton Aargau during deposition of the Geissberg Member, later progressively affected the eastern part of Canton Solothurn when succession 3 was sedimented. Growth of hermatypic corals stepped back from near Olten during sedimentation of succession 3 to Balsthal when the lowermost Reuchenette Formation was deposited there (fig. 173). Accelerated endogenic subsidence advancing with time to the west is the probable cause of this. No explanation can be given why the Gerstenhübel Beds in the Effingen Member between Olten and Villigen, and again the Villigen Formation between Aarau and Villigen, were apparently laid down on a level seafloor (fig. 173).

Deep drilling in northern Switzerland in search of an underground repository of nuclear waste revealed that the pre-Mesozoic rocks below northern Switzerland are intersected by faults at close intervals. Müller et al. (1984:112) stated that some of these faults were reactivated in Mesozoic time. Such a synsedimentary fault that was driven by an endogenic process, independent of sedimentation, must have caused the difference in thickness of 60 m in the St-Ursanne Formation between Liesberg and Kleinlützel that was mentioned above. The fault could not be located. None of the synsedimentary, endogenically driven faults that must be assumed to have caused the variation in the thickness of the investigated limestone formations could be directly observed. The measured sections are probably too far apart to locate such faults, let alone to recognize a regional fracture pattern.

Regional variation in the isostatic adjustment of lithosphere blocks that was caused by lateral shifting of deposition of thick sedimentary units is represented in figures 187A–C, as if deformation between basement blocks were flexural. This was done, because faults driven by an *exogenic* process could not be located. The difference in basement subsidence between the thick succession 1 in northwestern Switzerland and the adjacent starved basin occurred between Sornetan and Péry (fig. 173) in a belt that was about 20 km wide (fig. 187B). The width of this belt shrinks to less than 10 km south of Basel (see above). Gygi (1986:471) concluded that the regional difference in the adjustment of the lithosphere to loading with sediment or water first under the thick, proximal succession 1, and then under the thick, proximal part of succession 2 in the adjacent basin (fig. 187A–C) was local isostatic, this is to say it occurred along exogenically driven fractures in the lithosphere in the sense of Steckler & Watts (1978:1). Flexural deformation of the lithosphere in a belt only 10–20 km wide was ruled out. Synsedimentary faults driven by lateral, regional variation in loading of the lithosphere must have existed and were intimated in figure 6 by Gygi & Persoz (1987). The direction of movement along exogenically driven faults in the belt between thick succession 1 and adjacent thick succession 2 must have been reversed when deposition of the proximal succession 1 ceased and sedimentation of the thick, proximal succession 2 began in the starved basin.

The pattern of the margins of carbonate platforms that evolved in northern Switzerland between the Early Bathonian and the Early Kimmeridgian was represented by Gygi (1986, fig. 1). The geographic configuration of these platform margins is unrelated to the fracture pattern that Allenbach (2001, fig. 22) alleged to have controlled sedimentation in Late Jurassic time in the region.

The measured thickness of limestone formations was found to vary from section to section. These minor differences and even the variation in thickness of the St-Ursanne Formation of 60 m between Liesberg and Kleinlützel were thought to be only of local importance by Gygi (1986). Synsedimentary tectonics as were represented in figure 3 by Gygi (1986) were reconstructed under the assumption that endogenic subsidence was on average equal in the whole of northern Switzerland in Late Jurassic time (Gygi, 1986:470, calculation step no. 7). This had to be reconsidered in view of the different opinions arrived at by Allenbach (2001 and 2002). As it was stated above, subsidence of the base of succession 3 varied by 30 m between eastern Canton Solothurn and Canton Aargau. This was mainly the result of substantial, *regional* variation in *endogenic* subsidence (fig. 187C–D, compare with fig. 3C–D by Gygi, 1986). The calculations of *relative* sea-level rise during deposition of successions 1–3 and of water depth at the end of sedimentation of succession 3 near Schaffhausen that were published by Gygi (1986) were therefore based on an assumption that now turned out to be wrong.

Allenbach (2001) thought that endogenic subsidence was the most important process that controlled sedimentation of the Late Jurassic in northern Switzerland. He related the varying thicknesses of coeval lithostratigraphic units to movement along fractures of pre-Mesozoic age that he inferred to have been reactivated by an endogenic process in Late Jurassic time. A pattern of endogenically driven, synsedimentary faults as was envisaged by Allenbach will perhaps emerge in the future when all of the published and unpublished sections of sediments of Late Jurassic age that were measured in the region are evaluated. This was beyond the scope of the present study. Synsedimentary tectonics are now *qualitatively* well-documented to have occurred during deposition of sediments of Late Jurassic age in northern Switzerland. There was a *complicated interaction between endogenic and exogenic subsidence*. The change from shallowing-upward tendency during sedimentation of succession 2 in Canton Aargau to deepening-upward tendency when succession 3 was deposited above, can only be recognized when the vertical change in the composition of the macrofauna in succession 3 is considered. This change was caused by regional variation in the rate of endogenic subsidence. Synsedimentary tectonics cannot be elaborated without taking exogenic subsidence into account. Exogenic subsidence as caused by loading of the lithosphere with sediments and additional water was in the investigated region probably more important than endogenic subsidence. Both processes have as yet to be quantified more accurately. In order to do this, the following data and processes have to be taken into account: water depth, detailed time correlations, variation in sedimentation rates, the amount of compaction mainly of muddy sediment, isostasy and the resulting geometry of sedimentary bodies.

9.18 Palaeoecology of ammonites

9.18.1 Water depth

Fairly well-preserved ammonites were found in sediments that were laid down in very shallow water. The *Lithacosphinctes* J 30530 from the uppermost Balsthal Formation near Balsthal (bed no. 9 of the unpublished section RG 439, as figured by Gygi, 1995, fig. 19) was embedded in calcareous oolite at a water depth of at most a few meters. A depth of deposition of the same order can be assumed for the *Lithacosphinctes* that was found in bed no. 4 of the unpublished section RG 457 in Schachlete valley near Dittingen, Canton Basel-Landschaft. This specimen is from the oolitic facies of the Laufen Member and was figured by Gygi (1995, fig. 20). It is possible that the two specimens were empty shells that drifted from deeper into very shallow water.

The ammonites found in the lagoonal Buix Member of the upper St-Ursanne Formation near St-Ursanne that were figured by Gygi (1995) are all perisphinctids. The ammonites are not abundant, but numerous enough that the possibility must be envisaged that they lived at least temporally in the lagoon at a water depth of less than 10 m. Hermatypic corals are most abundant in this environment. The ammonites in the lower Reuchenette Formation of Olten were probably part of a sta-

ble community living at a water depth of about 30 m. The a
monites are all perisphinctaceans. Bivalves prevailed in t
macrofauna. At Mellikon, at a greater depth, ammonites a
with about 80% most common in the macrofauna of the low
Baden Member. Perisphinctaceans predominate in the a
monite fauna of the lower Baden Member at Mellikon. T
depth of deposition of the lower Schwarzbach Formation ne
Schaffhausen must have been substantially greater than ne
Mellikon, but the abundance of ammonites in the macrofau
near Schaffhausen is again about 80%, and it did not increa
with growing water depth as compared with Mellikon. O
the composition of the ammonite fauna changed betwe
Mellikon and Schaffhausen with increasing water dep
Perisphinctaceans with the exception of Aspidoceratidae a
almost 50% of the ammonites collected from the low
Schwarzbach Formation in excavation RG 239 near Scha
hausen. The percentage of Haplocerataceae is there o
slightly greater than near Mellikon (fig. 188A).

Ammonites are rare in very shallow water. At a depth of abo
30 m in the Early Kimmeridgian, ammonites are 19% of t
macrofauna and bivalves 55%. From a depth of about 40
down (see below), ammonites are roughly 80% of the macr
fauna in the Kimmeridgian. This percentage does not increa
to the greater water depth that probably existed ne
Schaffhausen, but the composition of the ammonite fau
varied further from a depth of about 40 m downward. Con
quently, the abundance of ammonites in the macrofau
grows from shallow water with increasing depth to a certa
maximum percentage. This remains to be about the same w
further increasing depth. Both the abundance and the comp
sition of the ammonite fauna vary with water depth. It is e
dent from the rapid *vertical* transition from the fossil bed
the middle of the distal part of the Sornetan Member, with
macrofauna of mostly ammonites, to the upper Sornet
Member with mostly bivalves, and of the *lateral*, isochrono
succession of Hypselocyclum age between Olten and Schöne
werd to the east, that the small difference in water depth
only about 10 m is sufficient for an abrupt change in the co
position of the macrofauna from predominance of bivalves
prevalence of ammonites (fig. 188A).

In the Schellenbrücke Bed of the late Early Oxfordian in Ca
ton Aargau that is from at a water depth of about 90 m, a
monites are 86%, and belemnites are less than 1% of t
macrofauna (table 78). In the coeval Glaukonitsandmerg
Bed, at a depth that was substantially greater than 100 m, a
monites were 68% and belemnites 18% of the macrofauna.
cephalopods together amount to 86% of the macrofauna
this unit (table 78). In the Mumienkalk Bed further up in su
cession 1 of Canton Schaffhausen, at an even greater depth
deposition than that of the Glaukonitsandmergel Bed, a
monites are 86% and belemnites less than 1% of the macr
fauna. Cephalopods together were everywhere almost exac
86% of the macrofauna in the deep subtidal zone during d
position of succession 1 in Canton Schaffhausen. Wh
belemnites are abundant as they are for an unknown reason
the Glaukonitsandmergel Bed, then the percentage of a
monites in the cephalopod fauna drops proportionally to t
abundance of belemnites. This may mean that both a
monites and belemnites competed for similar prey in the sa
environment. Belemnites are generally rare in sediments of t
Late Jurassic of northern Switzerland, except in the Early C

			Schellenbrücke Bed			Glaukonitsandmergel		
Porifera			P	–		1	0.2%	
Brachiopoda:	Rhynchonellida		15	1.0%		6	1.1%	
	Terebratulacea		13	0.8%		3	0.5%	
Bivalvia			41	2.6%		32	5.7%	
Gastropoda			123	7.9%		9	1.6%	
Cephalopoda:	Nautilaceae		7	0.4%		–	–	
		Phylloceratidae	14	0.9%		2	0.4%	
		Haploceratаceae	124	7.9%		132	23.4%	
	Ammonoidea	Cardioceratidae	568	36.4%	85.6%	73	12.9%	68.1%
		Perisphinctidae	565	36.2%		162	28.6%	
		Aspidoceratidae	65	4.2%		16	2.8%	
	Belemnoidea		7	0.4%		102	18.0%	
Echinodermata:	Echinoidea		9	0.6%		5	0.9%	
	Crinoidea: stem fragments		–	–		4	0.7%	
Vertebrata:	individual shark teeth		10	0.7%		18	3.2%	
Total number of specimens:			1561	100%		565	100%	

P: Parts of incompletely fossilized specimens present

Table 78. Composition of the macrofauna collected from the Schellenbrücke Bed in Canton Aargau and from the coeval Glaukonitsandmergel Bed in Canton Schaffhausen, Cordatum Subchron, Early Oxfordian.
After table 1 in Gygi (1981).

Siliceous sponges:	Lithistida and Hexactinellida	8	0.4%	
Brachiopoda:	Rhynchonellida	33	1.8%	
	Terebratulacea	88	4.7%	
Bivalvia		39	2.0%	
Gastropoda		9	0.5%	
Cephalopoda:	Nautilaceae	1	0.05%	
	Phylloceratidae	6	0.35%	
	Haploceraceae	728	38.9%	
	Cardioceratidae	13	0.7%	86.5%
	Persiphinctidae	850	45.4%	
	Aspidoceratidae	22	1.2%	
	Belemnoidea (parts)	13	0.7%	
Echinodermata:	Echinoidea	55	2.9%	
	Crinoidea (parts)	7	0.4%	
Total		1872	100%	

Table 79. Composition of the macrofauna collected from the Mumienkalk Bed in several sections in Canton Schaffhausen and near Blumberg, southern Germany.
Excavations RG 80, RG 207 and RG 212 near Siblingen, RG 81a and b near Gächlingen, and RG 88 near Blumberg.
Age: Antecedens and Luciaeformis Subchron of the Transversarium Chron, Middle Oxfordian.
After table 12 in Gygi et al. (1979).

	Canton Aargau		Canton Schaffhausen	
	Birmenstorf Member, normal facies with glauconite, Luciaeformis Subzone Excavations RG 60, 210, 225, 230, 276		Unnamed glauconitic marl, ca 0.2 m thick, above Mumienkalk Bed, Luciaeformis Subzone, Excavations RG 81a and b, 207, 212	
	Individuals	Percentages	Individuals	Percentages
Phylloceratidae	15	0.8	–	–
Haplocerataceae	912	**51.0**	86	**49.1**
Cardioceratidae	15	0.8	1	0.6
Persiphinctidae	780	44.0	85	48.6
Aspidoceratidae	60	3.4	3	1.7
	1782	100	175	100
			Mumienkalk Bed, with glauconite Late Antecedens and Luciaeformis Subzone Excavations RG 80, 81a and b, 88, 207, 212	
			Individuals	Percentages
Phylloceratidae			6	0.4
Haplocerataceae			728	**45.0**
Cardioceratidae			13	0.8
Persiphinctidae	Insufficient data		850	52.5
Aspidoceratidae			22	1.3
			1619	100
	Schellenbrücke Bed, iron oolitic Cordatum Subzone, Excavation RG 208		Glaukonitsandmergel Bed, Cordatum Subzone Excavations RG 81a and b, 207, 212	
	Individuals	Percentages	Individuals	Percentages
Phylloceratidae	14	1.0	2	0.5
Haplocerataceae	124	**9.3**	132	**34.3**
Cardioceratidae	568	42.5	73	18.9
Persiphinctidae	565	42.3	162	42.1
Aspidoceratidae	65	4.9	16	4.2
	1336	100	385	100

Table 80. Vertical and lateral variation of the composition of the ammonite fauna between the Cordatum and the Luciaeformis Subchron in Canton Aargau and in Canton Schaffhausen.
Reprinted from table 1 in Gygi (1986).

fordian Glaukonitsandmergel Bed of Canton Schaffhausen and in beds no. 6 and 7a of the earliest Oxfordian in excavation RG 208 near Ueken, Canton Aargau (Gygi, 1977, pl. 11, section 2).

The percentage of Haplocerataceae in the ammonite fauna grows with increasing water depth both laterally and vertically. The lateral change can be read from figure 188A. The percentage is 24% in the lower Schwarzbach Formation of the Early Kimmeridgian near Schaffhausen, where the water was probably at least 80 m deep. The same trend in Haplocerataceae exists in the Oxfordian. The percentage of Haploceratacea grows vertically from 34% at more than 100 m depth in the Glaukonitsandmergel Bed to 45% at greater depth in the Mumienkalk Bed above and to 49% in the glauconitic marl above the Mumienkalk Bed from an even greater depth that is now estimated at 130 m in Canton Schaffhausen (table 80). The percentage of Haplocerataceae grows laterally from 9% in the Schellenbrücke Bed of the Cordatum Subchron to 34% in the coeval Glaukonitsandmergel Bed, a sediment from substantially deeper water (table 80). But the percentage of Haplocerataceae in an ammonite fauna cannot be used to estimate water depth. The uncondensed facies of the Birmenstorf Member in Canton Aargau was sedimented at a depth of about 110 m. Haplocerataceae are 51% of the ammonite fauna in this facies. In the coeval, glauconitic marl above the Mumienkalk Bed in Canton Schaffhausen that was sedimented at

greater depth, the percentage is somewhat less, this is to say 49% (table 80).
Perisphinctaceans are the only ammonites that were found in sediments from very shallow water. Unlike Haplocerataceae, Perisphinctaceae occurred in the ammonite fauna at any water depth that existed in northern Switzerland from the beginning of the Oxfordian to the Early Kimmeridgian. The same taxa of specific rank can occur both in sediments from very shallow water and from a depth greater than 100 m. Examples of this are *Perisphinctes (Perisphinctes) alatus* Enay and *Perisphinctes (Dichotomosphinctes) dobrogensis* Simionescu that were both figured by Gygi (1995) from the Buix Member of the upper St-Ursanne Formation and by Gygi (2001) from the Birmenstorf Member of Canton Aargau and from the Mumienkalk Bed of Canton Schaffhausen. Perisphinctaceae are therefore the ammonites best suited for biostratigraphic time correlations in the investigated sediments of the Late Jurassic. The dwarf ammonite fauna of the Renggeri Member is evidence that most, if not all ammonites lived in close relation to the bottom, because only the bottom water was oxygen-deficient when that member was sedimented. The fact that the abundance of ammonites in the macrofauna increases from very shallow water to a certain depth, is further evidence that the ammonites of the Late Jurassic in northern Switzerland lived near the bottom. This corroborates qualitatively one of the conclusions arrived at by Ziegler (1967).

9.18.2 Sedimentation rate

Gygi (1999) investigated the influence of the sedimentation rate of mud on the abundance of ammonites in deeper water. He found that ammonites are abundant from the Glaukonitsandmergel Bed upward to the glauconitic marl above the Mumienkalk Bed in Canton Schaffhausen (op.cit., fig. 3). These beds with a combined thickness of only about 0.5 m near Gächlingen were sedimented during a time of somewhat less than one million years, this is to say at a very low average rate. Ammonites were still fairly abundant in the normal, uncondensed facies of the Birmenstorf Member in Canton Aargau (Gygi, 1999, fig. 2), when the average sedimentation rate was somewhat greater, about 185 mm per 10000 years. As soon as the rate of mud sedimentation rose significantly above this moderate figure, when deposition of the subsequent Effingen Member began, ammonites became increasingly rare.
The abundance of ammonites is unusually great in the condensed Schellenbrücke Bed. In the condensed bed directly above, at the base of the Birmenstorf Member, ammonites are rare. Consequently, ammonite abundance in condensed beds that were sedimented at a similar, very low rate and at almost equal depth can vary greatly. Tolerance of ammonites of mud deposition was apparently low. Gygi (1999:136) concluded that ammonites are primarily abundant only where the rate of mud sedimentation was less than about 10 mm per 10000 years. For comparison, hermatypic corals were very abundant in the Liesberg Member at the type locality of the member near Liesberg, Canton Basel-Landschaft, where the rate of deposition of argillaceous mud was as much as 2.5 m per 10000 years (Gygi, 1999, fig. 1), this is to say 250 times greater. The optimal habitat of ammonites was in a water depth greater than about 40 m, where the average rate of mud sedimentation was low.

9.18.3 Oxygen content of the water

The ammonites fossilized as casts of iron sulfide in the Renggeri Member were very probably living in the bottom water that had a content of dissolved oxygen the order of one milliliter per liter of water or less. They apparently could tolerate a reduction of the oxygen content in their habitat to 20% or even less of the normal content that Gygi (1999:130) estimated at about five milliliters of dissolved oxygen per liter of bottom water. The ammonites reacted to minimally aerobic to dysaerobic conditions of the water in their habitat by reducing their adult size, as Ziegler (1963:98) concluded.

9.18.4 Salinity of the water

The several ammonites that were found in the lagoonal Buix Member between coral patch reefs near St-Ursanne are evidence that ammonites could live at least temporally where the water was at most 10 m deep. The thriving lagoon reefs in the unit indicate that the salinity of the water was then normal.
The lagoon in which the Hauptmumienbank Member was laid down had a great areal extent. At several localities, the upper surface of the Hauptmumienbank Member (fig. 183) and of the coeval Steinebach Member (fig. 176) was subaerially exposed after sedimentation ceased. This is an indication that the depth of deposition of the Hauptmumienbank Member was only slightly greater than that of the calcareous oolite sandbank of the Steinebach Member that rimmed the lagoon. Too shallow water may then be the main reason for the absence of ammonites in the Hauptmumienbank Member. Gygi & Persoz (1987, fig. 2C) documented that salinity was at least temporally above-normal in the lagoon where the Hauptmumienbank Member was laid down. This is probably another reason why no ammonites were found to date in the Hauptmumienbank Member.
Dolomitization was common in the calcareous oolite of the Verena Member, and even gypsum occurs at one locality in the member (see above). The rare coral bioherms within the Verena Member (fig. 173) are evidence that the salinity of the very shallow water in that the oolite was formed was at times normal. Salinity must have varied greatly between normal and hypersaline during deposition of the Verena Member. Too slight a water depth that was never more than 10 m, and the salinity that was often much above-normal were probably the reasons why no ammonites were ever found so far in the Verena Member.
The lagoonal Laufen Member is locally very fossiliferous. The worms *Cycloserpula socialis* (Goldfuss) can be more than 50% of the rock volume (Gygi, 2000a, fig. 19). The great abundance and the low diversity of the macrofauna as well as the fact that serpulids can be the most common element of the macrofauna are an indication that the salinity of the water was at times lower than normal when the Laufen Member was sedimented. The only ammonite known from the Laufen Member probably drifted *post mortem* as an empty shell from deeper water into the environment (see above). This is an indication that ammonites were a strictly stenohaline group within the marine macrofauna.

10. Conclusions

10.1 Taxonomy of perisphinctacean ammonites

A comprehensive taxonomy of biota, history of sedimentation and palaeoecology can only be established when a sufficient number of specimens of the macrofauna collected from *in situ* is available. This is why the author collected since 1962, and since 1970 with the help of his wife Sylvia, all of the well-preserved macrofossils that were found in sediments of Late Jurassic age in northern Switzerland. Among the collected macrofossils are many thousands of ammonites. More than 6000 ammonite specimens were prepared by the author and his wife. Most ammonite groups out of this material were studied and figured by the author and by several collegues since 1966. 1444 perisphinctacean ammonites from the Late Oxfordian and the Kimmeridgian were used for this study. 53 of the taxa described here are figured for the first time from Swiss localities. This material is of more than regional interest, because it includes very large and some giant specimens. Representatives of the very large genera *Involuticeras, Balticeras* and *Pachypictonia* can only be identified and distinguished when adult and nearly complete specimens are at hand. Occurrence of the subboreal genus *Ringsteadia* in northern Switzerland could be ascertained, but no species previously described from England were found. *Ringsteadia* and *Balticeras* are separate genera that succeeded each other in time.

Provided that the taxonomy of ammonites is studied in detail, ammonites are excellent tools for time correlation. This was recognized early in the 19th century. Ziegler (1963; 1967) pointed out how much information ammonites of the Late Jurassic give of palaeoecology, mainly of water depth. Additional evidence of this and more accurate data are presented in this study. Palaeoecologic evidence based on ammonites could even be used in order to revise synsedimentary tectonics that were worked out for the first time by Gygi (1986, fig. 3).

10.2 Biostratigraphy

The biostratigraphy of ammonites from the Oxfordian Bimammatum Zone to the Kimmeridgian Divisum Zone is reviewed. Ammonites from all zones and subzones from the base of the Upper Jurassic up to the Divisum Zone are now described and figured from northern Switzerland. These ammonites are listed together with the corresponding references in figure 174.

Morphotypes A, B and C of *Sutneria platynota* (Reinecke) as were described by Schairer (1970) succeed each other in time on the Franconian Alb in southern Germany. Only morphotypes A and C were found by R. & S. Gygi in section RG 239 near Schaffhausen (fig. 160), and morphotype A occurs alone in section RG 70 near Mellikon in northern Switzerland. Subtle differences in the environment that are not documented in the sediments investigated are probably the cause of presence or absence of one of these morphotypes in a given sediment. This is the reason why no ammonite horizons are discerned i this study.

10.3 Palaeogeography and palaeoclimate

Northern Switzerland was in Late Jurassic time part of an ep continental sea north of the Tethys (Gygi, 2000a, fig. 2). Th siliciclastic sediment supplied to this shallow, Rhodan Swabian basin came from the Ardenne-Rhenan Massif (Gyg 2000a, fig. 63). Coral bioherms, some of them reefs, docume that the climate was either tropical or subtropical. Some of th hermatypic corals have distinct accretion bands. This is ev dence that the climate of the region was seasonal and therefo subtropical.

Times of humid climate alternated with drier terms. Main argillaceous formations like the Bärschwil and the Wildeg Formation are thought to be evidence of a climate with rel tively much rainfall. This is concluded from the occurrence thin lignite layers and from the primary absence of evaporit in the carbonate Günsberg Formation, a time equivalent the mainly argillaceous Wildegg Formation. The climate mu have been rather dry when impure gypsum was locally preci itated in the Verena Member of the pure carbonate Balsth Formation. If the mostly argillaceous Bärschwil Formatic was indeed sedimented during a time with relatively muc rainfall, and the pure carbonate St-Ursanne Formation abo in a drier climate, this would mean that long-term humid dry times, respectively, were of unequal duration (Gygi, 199 fig. 1).

There was enough rainfall for plants to grow on nearby lar when the carbonate platform of the St-Ursanne Formatic was sedimented. Pümpin (1965, fig. 21) found the leaf of land plant in the lagoonal Buix Member near St-Ursann Canton Jura. When the mostly carbonate Reuchenette Forma tion was laid down, vegetation on land was plentiful enoug that large plant-eating dinosaurs could make a living. T plants themselves are not preserved, but large, circular a very distinct footprints of sauropod dinosaurs on an ancie tidal flat were found by the author in 1986 (Gygi, 2000a:49 a pl. 42) in the eastern quarry of Steingrueben near Oberdo Canton Solothurn. C. Meyer found more dinosaur footprir on a lower bedding plane of the same quarry in 1987 (Mey 1990:391). Another ancient tidal flat with unequivocal, d tinct dinosaur footprints above the Banné Member of t Reuchenette Formation was excavated in 2002 near Court doux west of Porrentruy in Canton Jura.

10.4 Palaeoecology

Supratidal environments are documented by thin lignite la ers, palaeosols with rootlets and by presumed calcrete nodul some of them with radially oriented calcite rays below the su face, that were probably not published to date. Stromatolites with birdseye pores and prism cracks are evidence of the upper intertidal zone. In shallow marine environments, calcareous ooids were formed and sedimented between the lower tidal zone and a depth not greater than about 10 m. Marine iron-ooids can be *accreted*, according to the review by Gygi (1981), at depths ranging from very shallow water down to about 100 m. The present study confirms this and gives additional evidence. Pure, cauliflower glauconite pellets were formed at a water depth that was greater than 100 m. If the bathymetric ranges of marine iron-ooid accretion and formation of cauliflower glauconite pellets overlap, then the overlapping is insignificant. The bathymetric boundary between iron-ooid and cauliflower glauconite formation might therefore turn out in the future to be a good indicator of water depth, provided that the existence of such a boundary can be confirmed in comparable successions elsewhere. The sedimentologic marks of water depth were used for the bathymetric calibration of marine macrofaunas. Finer differences of water depth in the deep subtidal zone can be read from variations in the composition of the ammonite fauna of the Early Kimmeridgian, but these differences are difficult to quantify bathymetrically.

The greatest depth where hermatypic corals could survive was about 20 m. The platy, hermatypic corals of the Liesberg Member grew in an environment where argillaceous mud was sedimented at a high rate. Much clay minerals were in suspension of the water in which the coral bioherms and biostromes of the Günsberg Formation grew. Ahermatypic corals are rare. Small, solitary specimens were found in a sponge bioherm of the Villigen Formation near Mellikon (Gygi, 1969a, pl. 6:23, right part) and in the lower Schwarzbach Formation in excavation RG 239, bed no. 20, near Schaffhausen. The ahermatypic corals lived in considerably deeper water than the hermatypic corals that occur in the studied sediments. Bivalves prevailed in the macrofauna of the very shallow lagoon of the Banné Member and in open water from a depth of 20 m to less than 40 m. Large species of the genus *Pholadomya* seem to be especially well-suited as indicators of water depth varying between about 20 and 30 m. They can be abundant in the upper Sornetan Member ("Pholadomyen" of Etallon, 1862), very abundant in the Crenularis Member near Villigen, and abundant in the lower Reuchenette Formation near Olten. Ammonites could live maybe permanently at a depth of less than 10 m in the lagoon of the Buix Member in the upper St-Ursanne Formation. They are uncommon in that environment, but they are fairly abundant at a depth estimated at 30 m where bivalves are most common in the lower Reuchenette Formation near Olten. Ammonites begin to prevail in the macrofauna when the water depth approaches 40 m. The small difference in water depth of about 10 m, between 30 and 40 m, was probably sufficient to separate bivalve-dominated macrofaunas living in water less than about 30 m deep from ammonite-dominated macrofaunas that occurred at a depth greater than about 40 m. This abrupt faunal change was observed as well in vertical succession between the fossil bed of the Cordatum Subchron with mostly ammonites about halfway up in the distal Sornetan Member (Gygi & Persoz, 1986, table 2), and the upper Sornetan Member with mostly bivalves. In a lateral, isochronous facies transition of Hypselocyclum age, the change was observed in the lower Reuchenette Formation between Olten and Schönenwerd 10 km to the east-northeast. Ammonites become 80% of the macrofauna from a depth of about 40 m. When the water depth further increases, this percentage does not grow significantly in the Kimmeridgian.

The abundance of ammonites in a macrofauna and the composition of an ammonite fauna depend on water depth. Therefore, the ammonites collected from sediments laid down in normally aerated water that were studied by the author, lived in close relation to the sea bottom. This is confirmed by the numerous ammonites that were collected from *in situ* in the Renggeri Member. The great majority of these ammonites are dwarf and must have lived in the oxygen-poor bottom water. Perisphinctaceae are the only ammonites that were found in sediments from very shallow water. Aspidoceratidae within this superfamily make their first appearance at a depth of about 30 m and become more abundant with growing depth. No Haploceratacеae were found in sediments from very shallow water. The percentage of Haploceratacеae in the ammonite fauna generally grows with increasing depth, but it is so variable at a given depth that it is not diagnostic of water depth. Conversely, the abundance of Perisphinctaceae among ammonites steadily decreases with growing depth. These trends in Perisphinctaceae and in Haploceratacеae were observed both in isochronous, lateral, and in vertical facies successions.

The sedimentation rate of mud in the deeper subtidal zone has much influence on the primary abundance of ammonites. These cephalopods that lived in close relation to the bottom could, in contrast to certain, mainly platy hermatypic corals, tolerate but a low rate of mud sedimentation. Ammonites could live in water with a low oxygen content that was 20% or less of the normal level. They adapted to such an environment by reducing their adult size. Ammonites were therefore sensitive of facies. On the other hand, they are excellent guide fossils for time correlation because of their especially high evolution rate, and because they occur in the studied epicontinental sediments from very shallow water to the greatest depth that could be identified. Perisphinctacean ammonites are best suited for biostratigraphic time correlations within the investigated sediments, because they were least dependent of facies, mainly of varying water depth. Detailed study of the taxonomy of several ammonite groups that were collected from *in situ* in a well-defined, regional frame of reference, and knowledge of sedimentology are the key tools used in reconstructing the sedimentary geology that was investigated by the author since 1962.

10.5 Synsedimentary tectonics

Varying rates of sedimentation, shallowing-upward or deepening-upward tendency in a sedimentary succession, the geometry and the palaeobathymetry of sedimentary bodies gave some information about synsedimentary tectonics. Considering the ample evidence of the process presented by Gygi (1986), there can now be no doubt that synsedimentary tectonics *did* occur during deposition of the studied sediments. Nondeposition at the floor of an epicontinental basin and the submarine hiatuses resulting from this must be carefully distinguished from hiatuses that evolved as a consequence of subaerial exposure.

Evidence of a submarine hiatus is a marine macrofauna in the sediments both below and above the hiatus, especially when ammonites prevail in the fauna below and above. Subaerial exposure must be concluded to be the cause of a hiatus, if there is for instance calcareous oolite below, a sediment from very shallow water, when the hiatus is above an erosion surface with a significant relief like that at the top of the Balsthal Formation near Balsthal, and when there is a palaeosol above the hiatus. Very much time can be represented by a submarine hiatus, even when the hiatus can only be seen at close distance like that in section RG 226 near Veltheim, Canton Aargau. Conversely, the subaerial hiatus at the base of the Reuchenette Formation near Balsthal that is conspicuous from a distance of 2 km evolved during probably only a fraction of an ammonite chron.

It is evident from the history of sedimentation of succession 1 and 2 between northwestern Switzerland and the region of Balsthal that marine, epicontinental sediments create a large part of their final accommodation space by their own weight that causes the basement to subside under the load. The *sum of exogenic subsidence* during deposition of the two successions in that region must have been substantially greater than the *average amount of endogenic subsidence* at the same time. Differences of endogenic subsidence of tens of meters could evolve during a relatively short time over a short horizontal distance like in the St-Ursanne Formation north of Liesberg. A lesser, but regional difference in endogenic subsidence must have evolved during deposition of succession 3 between eastern Canton Solothurn and Canton Aargau. Endogenic a genic subsidence *can* and *must* be carefully distinguish was done before by Steckler & Watts (1978, fig. 6), wh investigated sedimentation on the extensional, "passive nental margin off New York in the time interval betw million years before present and the Recent. Both in t scale of their example and in the small scale of sedime into the Rhodano-Swabian basin investigated by the exogenic subsidence proved to be quantitatively at leas portant as endogenic ("tectonic") subsidence.

Synsedimentary tectonics as represented by Gygi (198 were concluded both of the lithology and of the thic well as of the biota in sediments. Only a minor revisio was necessary in figure 187C and D of the present s thoroughly different course of synsedimentary tecto inferred by Bolliger & Burri (1970, fig. 30), and a Allenbach (2001:269), because these authors interpret densed beds to have been sedimented on a swell, and they took a hiatus indiscriminately to be evidence of su exposure. "Ups and downs" of basement blocks had th to be invoked by Allenbach (2002). It can be read fro 187 of the present study that exogenic subsidence as ca loading of the basement with sediment or water as a quence of a long-term, net eustatic sea-level rise, was ably more important than endogenic subsidence. D quantification of synsedimentary tectonics was attem Gygi (1986) and again for the present study, but it prov beyond of what the author could do.

11. General conclusions

The individually numbered sections measured in detail that are listed with coordinates in Gygi (2000a, table 1) are subdivided into numbered beds. The sections provide for the lithostratigraphic frame of reference on which all of the stratigraphic work carried out by the author since 1962 was based. Sedimentology and collecting of the entire macrofauna was used in facies analysis. Ammonites had a greater evolution rate than any of the other biota considered, and they are therefore best suited for biostratigraphy. They are most abundant in sediments from the deeper part of the epicontinental, Rhodano-Swabian basin. Ammonites are rare or can be absent in sediments from very shallow water. They give environmental information about depth, salinity and oxygenation of the water as well as an indication of the rate of mud sedimentation in deeper water.

An inventory of ammonites as close to completeness as possible was addressed, mainly by means of systematic excavations. An adequate sample of ammonites taken from *in situ* is a prerequisite for meaningful taxonomy. Taxonomy based on well-preserved ammonites labelled with an individual number, is indispensable for high-resolution biostratigraphy. Both the *abundance* of ammonites in the macrofauna of a given sediment, and especially the *composition* of the ammonite fauna, change with varying water depth. Environments of shallow water can therefore be *qualitatively* discerned from environments of deeper water according to the macrofauna. A complete ammonite biostratigraphy including all of the zones and subzones could be stablished in sediments from relatively deep water, beginning in the latest Middle Jurassic and extending to the end of the Divisum Chron of the Late Jurassic. Non-palaeontologic methods of time correlation like mineral or sequence stratigraphy, that are in some cases the only means for detailed time correlation of sediments from very shallow water, could be calibrated with ammonite biostratigraphy. Conversely, time correlation with nonpalaeontologic methods of sediments from deeper water can sometimes be made with a precision that is not matched by biostratigraphy, as for instance in the Knollen Bed.

Marine sedimentation mainly depends on the initial water depth of the basin, of sea-level changes, of the distance of the locus of sedimentation from the shore, and of climate. Rates of sedimentation vary widely both vertically and laterally. Water depth can be estimated *quantitatively* from calcareous oolite that was formed and sedimented only in very shallow water. Iron ooids could be *accreted* from a depth of less than 10 m down to a depth of about 100 m. The rate of accretion of iron ooids became very slow when water depth approached 100 m. At this depth, iron ooids occur only in thin, widespread beds where the iron ooids float in a matrix of mud that was sedimented at a low rate. Ammonites can be abundant and prevail in the macrofauna of such beds. When water depth increased to more than 100 m and the sedimentation rate remained to be low, then iron-ooid accretion ceased and was replaced by formation of pure, cauliflower glauconite pellets. This bathymetrically controlled facies change occurs in both vertical and in lateral, coeval successions and is an important depth mark in deeper water.

Once the age, the average thickness, the sedimentation rate and the depth of deposition of sediments are established in a given succession, then the process of basement subsidence can be identified, and the amount and the rate of subsidence can be estimated. Gygi (1986) pointed out that the regional difference in isostatic adjustment of the lithosphere that is caused by the shifting of sedimentary depocenters was relatively great and evolved over a comparatively short horizontal distance. The regional differences in adjustment of the lithosphere could therefore only occur along preexisting, deep fractures in the lithosphere that were reactivated by the great variation in regional sedimentation rates and by concomitant unequal loading of the basement, this is to say by an *exogenic* process. Studies in sedimentology and in ammonite taxonomy made by the author since 1986 corroborated this, with the exception of a minor revision in figure 187C–D in the present study in comparison with figure 3C–D in Gygi (1986).

An interaction of major exogenic and of on average minor endogenic processes controlled basement subsidence in northern Switzerland during the Late Jurassic. Endogenically driven movement along fractures in the lithosphere could displace basement blocks vertically by tens of meters in a relatively short time. Nevertheless, such substantial, endogenically driven faulting in the basement had no noticeable influence on the facies distribution in the sediments being laid down above the differentially subsiding basement blocks. No correlation could be found between the probable location of fractures that were active during sedimentation and that were certainly driven by an endogenic process, and the geographic configuration of carbonate platforms. The mode of progradation of carbonate platform margins in Oxfordian time is unrelated to the pattern of pre-Mesozoic fractures that could be identified to date in the basement.

Planar units laid down by aggradation, first of mainly argillaceous mud and then of carbonates, filled the proximal part of the basin from an initial depth of about 70 m at the beginning of the Late Jurassic up to sea level. A bank of shallowing-upward, argillaceous mud with a flat top thereby accumulated. Then the bank was capped with a carbonate platform when the climate became drier. The margin of the argillaceous mud bank and of the carbonate platform above did *not* prograde. Meanwhile, sedimentation of succession 1 on the flat bottom of the adjacent starved basin proceeded at a very low average rate. Water depth even somewhat increased during slow deposition of succession 1 in the basin, but at the same time, it rapidly decreased in northwestern Switzerland, because the sedimentation rate was much greater there. The iron-oolitic facies at the relatively deep and fairly flat basin floor was at the beginning of the Late Jurassic uniform between northwestern Switzerland and Canton Aargau. When the thick part of succession 1 was sedimented in the northwest up to sea level, a *vertical* facies change evolved from deep-water iron oolite with a macrofauna of mainly ammonites towards calcareous oolite with small coral bioherms from very shallow water at the margin of the carbonate platform. At the same time, facies in the starved basin changed vertically from iron-oolitic to glauconitic in the thin, slowly deposited beds because of deepening of the water. An ever increasing *lateral* difference in facies can be observed to have evolved within the sediments of the slope between the increasingly shallowing margin of thick succession 1 in the northwest and the adjacent basin floor that became slightly deeper during starved deposition at the same time.

Subsequent sedimentation of the mostly argillaceous Effingen Member of succession 2 into the starved basin first proceeded by sigmoids that prograded at a low declivity. Sedimentation of the Effingen Member in eastern Canton Solothurn occurred by aggradation with planar and shallowing-upward units similar to those in the Bärschwil Formation in northwestern Switzerland. Further in the distal direction, sedimentation returned to be progradational, mainly in the upper Effingen Member. It is as yet unknown what was the cause of variation in the geometry and internal structure of the investigated sedimentary bodies.

The marl-limestone successions no. 1–3 are probably the effect of long-term, climatic variations between times with more, and time intervals with less rainfall in a subtropical environment. Time resolution by means of ammonite biostratigraphy combined with mineral stratigraphy is sufficient to reveal that each of the three successions was sedimented during a different length of time. It can be read from figure 185 that succession 1 includes eight ammonite subzones, succession 2 five subzones, and succession 3 four subzones. Under the assumption that all of the ammonite subchrons represent the same length of time of about 300 000 years, then succession 1 was deposited during about 2.4 million years, succession 2 during 1.5 million years, and succession 3 during 1.2 million years. Moreover, according to figure 175, sedimentation of the argillaceous Bärschwil Formation in the lower part of succession 1 lasted almost two million years, sedimentation of the argillaceous Effingen Member in lower succession 2, according to figure 2 in Gygi (1999), about 1.3 million years, and that of the argillaceous Bure Member at the base of succession 3 in the northwest, according to figure 175 in this study, only about 100 000 years. The upper, carbonate part of succession 1 in northwestern Switzerland, the St-Ursanne Formation, represents a time span of abut 500 000 years, the carbonate Hauptmumienbank Member (fig. 185) and the coeval Geissberg Member in Canton Aargau (Gygi 1999, fig. 2) in the upper part of succession 2 between 100 000 and 200 000 years, and the carbonate Courgenay Formation of succession 3 about one million years.

Observations recorded above are evidence that eustatic sea-level rises *did* occur, that they must have been rapid, and that the individual pulses of sea-level rise were of greater magnitude than subsequent sea-level falls. The result of this is the sum of net eustatic sea-level rise during deposition of successions 1–3 that is evident from the sea-level curve as drawn by Gygi (1986, fig. 4). The net rise was estimated at that time to have been between 25 and 30 m (op.cit.:488). The greatest individual eustatic sea-level rises that occurred in Oxfordian time amounted to probably 10 m at most. This is more than ten times less than the sea-level rise of between 120 and 130 m that is now known to have occurred since the peak of the last glaciation of the Pleistocene to the present time.

The climatically controlled marl-limestone successions 1–3 and the sequences in the sense of P.R. Vail that he concluded to be the effect of eustatism, and that were discerned by P.R. Vail and A. Coe in Gygi et al. (1998), are incongruent. Some of th measured differential, vertical movements of the basemen that probably occurred along pre-Mesozoic faults during sedimentation in the Late Jurassic, were driven by processes in th earth interior. This synsedimentary block faulting could pro duce great differences in sediment thickness in a short time *lo cally*, but had no noticeable influence on the *average, regiona* thicknesses, nor on the mineral composition of the succession (argillaceous or carbonate facies, respectively), nor on th overall geometry of sedimentary bodies, nor on the palaeo geographic configuration of carbonate platforms. Conversely the great lateral variation in sedimentation rates and in the re sulting thicknesses of successions that were caused by the ini tial water depth of the epicontinental basin and by the grea areal variation in sediment supply, must have reactivated pre Mesozoic faults in the basement that were previously discov ered by deep drilling. This type of synsedimentary movemen along the faults was a *tectonic* process that was the effect o *exogenic* causes. This was hinted in figure 6 by Gygi & Perso (1987).

Sedimentary geology could appropriately be investigated onl after a taxonomic study of an adequate number of ammonite collected from *in situ* was made. Detailed time correlation were established using three different methods. The latera variation in the composition of whole, coeval macrofauna was analyzed quantitatively and was found to be dependent c water depth like in Recent seas. Depth was concluded fror sedimentology and from exact measurement and averaging c the thicknesses of clearly defined lithostratigraphic units tha were investigated in a great number of detailed sections.

This study highlights the importance of the insight of Gressl (1838–1841), that the composition of a given marine macro fauna is closely related to the lithology of the embedding rock a pattern that Gressly called facies. Gressly recognized that fa cies can be diagnostic of water depth. No less important ar the results of the present study corroborating B. Ziegler's cor clusion that ammonites cannot only be used for time correla tion. Ziegler (1963, 1967) pointed out that the *abundance* c ammonites in a given macrofauna, the *composition* of the am monite fauna, and certain modes of ammonite fossilizatio are indicative of facies, mainly of water depth. His conclusio from this, that most of the ammonites lived in close relation t the bottom of the sea, and that ammonites became abundar only from a minimum water depth of several tens of meters, substantiated by observations by the present author on th sediments of Late Jurassic age in northern Switzerland.

The summary of lithostratigraphy, detailed time correlation the history of sedimentation, and variations in the clima during the Late Jurassic in northern Switzerland as was pul lished by Gygi & Persoz (1986 and 1987) is fundamental to th present study. Gygi (1986) compared this with other Europea countries and presented convincing evidence that individu *eustatic* sea-level changes of as much as 10 m occurred in O fordian time. He named the processes of *endogenic* and *ex genic* subsidence and distinguished them according to th benchmark paper by Steckler & Watts (1978). The relation b tween the rates of endogenic basement subsidence and of se imentation leading to exogenic subsidence was visualized figure 3 by Gygi (1986). When the rate of marine sediment tion exeeded the rate of endogenic subsidence and of net e static sea-level rise as in succession 1 of northwestern Switze land or in succession 2 near Balsthal in Canton Solothurn, then the basin became shallower until it was filled up to sea level. These are *shallowing-upward successions. Deepening-upward successions* are for instance succession 1 in Canton Schaffhausen that was deposited at a *minimum average rate*, or succession 3 in Canton Aargau (Villigen Formation) that was laid down at a rate that was *normal* most of the time. Nondeposition and starved sedimentation amounting to a total of only 30 cm during ten million years and a concomitant relative sea-level rise led to an increase in water depth from about 0 m at the end of the Early Bathonian to more than 100 m in the early Middle Oxfordian in section RG 226 near Veltheim in Canton Aargau. This extreme case was documented with ammonites and sedimentology by Mangold & Gygi (1997).

An epicontinental basin can accommodate marine sediments with a total thickness that is much greater than the initial water depth *without intervention of endogenic subsidence of the basement*. This is the consequence of the *weight* of the sediments. By this force, older, unconsolidated sediments of mud grade are compacted, and uncemented carbonate silt or sand can be compacted by pressure solution at the contact between grains, provided that the weight of sediments above exceeds a certain minimum (a compacted thickness of at least 300 m). In addition, the sediments weigh down the whole lithosphere below isostatically. *Exogenic subsidence* as caused by sedimentation, that led to compaction of older sediments and to isostatic adjustment of the lithosphere, was responsible for the greater part of the difference between the initial depth of about 70 m of the basin in northwestern Switzerland at the beginning of the Late Jurassic and the primary thickness of 215 m of marine sediments that were accommodated in the basin, and filled it up to sea level (Gygi, 1986, fig. 1B). A minor cause of the growth of accommodation space for the marine sediments of proximal succession 1 was a net eustatic sea-level rise during sedimentation. This additional water load led to further basement subsidence.

The submarine topography of an epicontinental basin has a great influence on sedimentation. At the beginning of the Late Jurassic, the basin floor was about 70 m deep in northwestern Switzerland, and 80 m in eastern Canton Solothurn. A thin bed of iron oolite with a mud matrix and with a macrofauna of mostly ammonites that was laid down over the whole region, documents a significant water depth. The uniform facies and thickness of the bed is evidence that water depth did not vary significantly during deposition. Conversely, stromatolites with birdseye pores and with mud cracks that evolved during a time of exposure of probably weeks between spring tides in the Vorbourg Member (fig. 178) near the base of succession 2 in northwestern Switzerland and in the Günsberg Formation (fig. 177), are evidence of the upper intertidal zone. At the same time, the base of succession 2 in eastern Canton Solothurn and in Canton Aargau was mud-grade sediment with a macrofauna of mainly siliceous sponges and ammonites. This is evidence of a much greater water depth exceeding 100 m in the basin. Consequently, a depositional *slope* must have existed at that time in the lowermost part of succession 2 above succession 1. The lower part of succession 2 in Canton Aargau is the Effingen Member. A conspicuous, submarine truncation surface (reproduced as fig. 182 in this study) and a debris flow directly above were figured by Gygi & Persoz (1986, fig. 2–3). These are unequivocal documents of the existence of a depositional slope with a declivity that was sufficient that debris flows *could* occur in some places. However, the *average* depositional slopes of the upper Pichoux Formation and of the proximal Effingen Member were very slight, with a declivity of between only 0.5 and 1°. This is evident from plate 1 in Gygi & Persoz (1986). The scale to this plate indicates a great vertical exaggeration like in figure 173 of the present study.

The geometry of sedimentary bodies in successions 1–3 and the position of the principal time planes within the lithostratigraphic units were elaborated in plate 1 by Gygi & Persoz (1986). Sediment transport and climate were mainly discussed by Gygi (1986). Time correlations were based at that time on the taxonomy of Oxfordian ammonites as was published by the author and coworkers until 1982, and on mineral stratigraphy made by F. Persoz. It is worth mentioning that the history of sedimentation as represented in plate 1 by Gygi & Persoz (1986) was confirmed by further taxonomic work by the author on ammonites, mainly on perisphinctaceans, that give the most detailed information on regional biostratigraphy from the Middle Oxfordian on (Gygi, 1998, 2001, and in this study). This can be checked by comparing plate 1 by Gygi & Persoz (1986) with figure 173 in this study.

It can be concluded from the macrofossils that were collected and processed in northern Switzerland since 1962, that both the abundance and the composition of the ammonite fauna are diagnostic of water depth in a given time plane. However, evidence was presented that the relation between the abundance of a certain ammonite group and water depth changes with time. Representatives of the genus *Cardioceras* (Cardioceratidae) in the Cordatum Subchron of the Early Oxfordian are most abundant in the ammonite fauna of the fossil bed in the distal Sornetan Member that was sedimented at a water depth of about 40 m. The percentage of *Cardioceras* decreases in the ammonite fauna with growing water depth, and it is at a minimum in the Glaukonitsandmergel Bed from a depth greater than 100 m (Gygi & Marchand, 1993, fig. 4, and tab. 78 in this study). The opposite trend can be read from figure 188A. The cardioceratid genus *Amoeboceras* of Early Kimmeridgian age is most abundant in relatively deep water, and its percentage in the ammonite fauna decreases when the water depth diminishes.

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